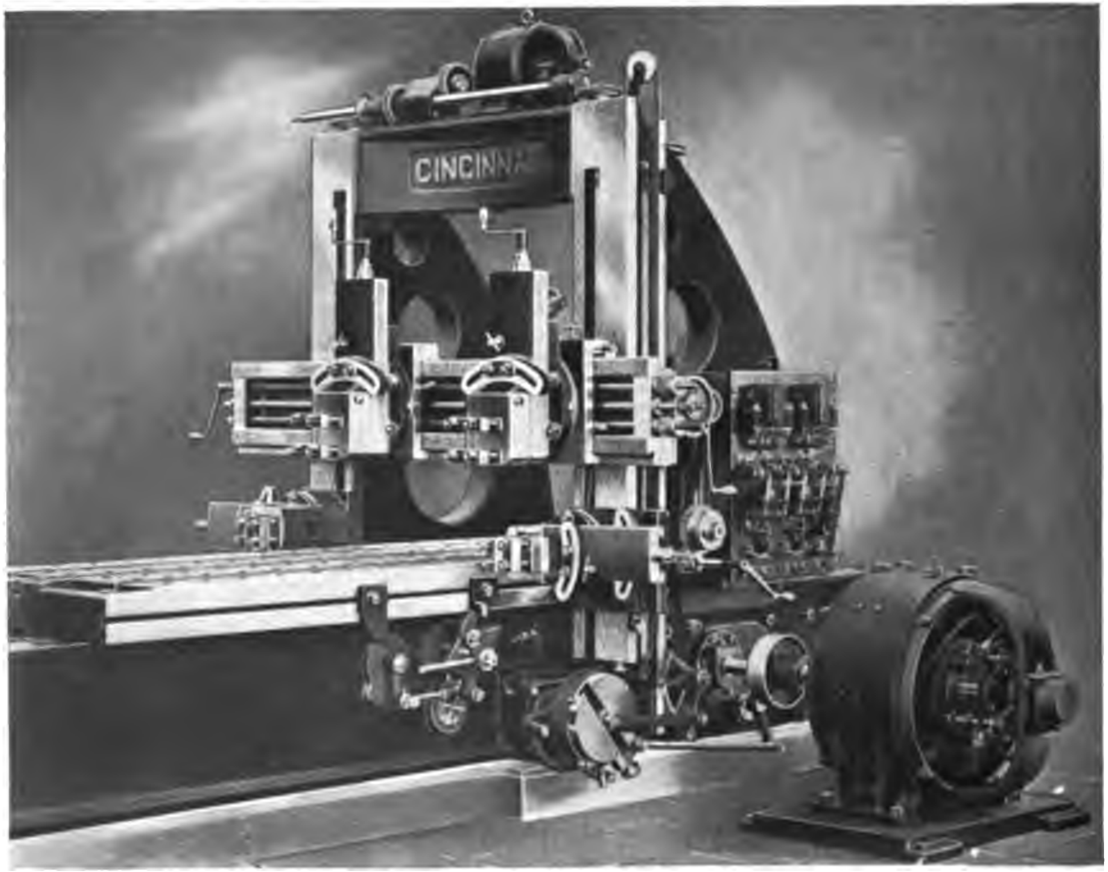


CINCINNATI REVERSIBLE MOT' 'RIVEN PLANER

Modern Shop Practice

A General Reference Work on

MACHINE SHOP PRACTICE AND MANAGEMENT, PRODUCTION MANUFACTURING, METALLURGY, WELDING, TOOL MAKING, TOOL DESIGN, DIE MAKING AND METAL STAMPING, FOUNDRY WORK, FORGING, PATTERN MAKING, MECHANICAL AND MACHINE DRAWING, ETC.

Editor-in-Chief

HOWARD MONROE RAYMOND, B. S.

Dean of Engineering, Armour Institute of Technology

Assisted by a Corps of

MECHANICAL ENGINEERS, DESIGNERS, AND SPECIALISTS IN SHOP METHODS AND MANAGEMENT

Illustrated with over Two Thousand Engravings

SIX VOLUMES

CHICAGO

AMERICAN TECHNICAL SOCIETY

1917

Editor-in-Chief

HOWARD MONROE RAYMOND, B. S.

Dean of Engineering, Armour Institute of Technology

Authors and Collaborators

EDWARD R. MARKHAM

Instructor in Shop Work, Harvard University and Rindge Technical School
Consulting Expert in Heat Treatment of Steel
Formerly Superintendent, Waltham Watch Tool Company
American Society of Mechanical Engineers

CHARLES L. GRIFFIN, S. B.

Assistant Engineer, The Solvay-Process Company
American Society of Mechanical Engineers

HOWARD P. FAIRFIELD

Assistant Professor of Machine Construction, Worcester Polytechnic Institute
American Society of Mechanical Engineers

JOHN LORD BACON

Consulting Engineer
Formerly Instructor in Forge Work, Lewis Institute, and Instructor in Shop Work, University of Chicago
American Society of Mechanical Engineers
Author of "Forge Practice"

BENJAMIN B. FREUD, B. S.

Associate Professor of Organic Chemistry, Armour Institute of Technology
Member, American Chemical Society
Member, American Electrochemical Society

ERVIN KENISON, S. B.

Associate Professor of Drawing and Descriptive Geometry, Massachusetts Institute of Technology

GEORGE W. CRAVENS

Mechanical and Electrical Engineer
Sales Manager, C and C Electric and Manufacturing Company

Authors and Collaborators—Continued

H. B. PULSIFER, S. B., Ch. E.

Assistant Professor of Metallurgy, Armour Institute of Technology
Member, American Chemical Society
Member, American Institute of Mining Engineers

FRANK E. SHAILOR

Mechanical Engineer
General Manager, Detroit Welding and Manufacturing Company

GLENN M. HOBBS, Ph. D.

Secretary and Educational Director, American School of Correspondence
Formerly Instructor in Physics, University of Chicago
American Physical Society

WALTER W. MONROE

Instructor in Pattern Making, Worcester Polytechnic Institute

FREDERICK W. TURNER

Head, Department of Pattern Making, Mechanic Arts High School, Boston

JAMES RITCHEY

Formerly Instructor in Wood-Working, Armour Institute of Technology

C. C. ADAMS, B. S.

Switchboard Engineer with General Electric Company

BURTON L. GRAY

Instructor in Foundry Practice, Worcester Polytechnic Institute
Member Foundrymen's Association

OSCAR E. PERRIGO, M. E.
Consulting Mechanical Engineer
Expert Patent Attorney
American Society of Mechanical Engineers
Author of "Modern Machine-Shop Construction, Equipment, and Management", "Lathe Design, Construction, and Operation", etc.

MORRIS A. HALL, B. S.
Formerly Managing Editor, *Motor Life*
Editor, *The Commercial Vehicle;* Editor, *The Automobile Journal, Motor Truck,* etc.
Author of "What Every Automobile Owner Should Know", "Motorist's First Aid Handbook", etc.
Formerly Associate Editor, *The Automobile*
Member, Society of Automobile Engineers
Member, American Society of Mechanical Engineers

ROBERT VALLETTE PERRY, B. S., M. E.
Associate Professor of Machine Design, Armour Institute of Technology

HAROLD W. ROBBINS, M. E.
Formerly Instructor, Lewis Institute, and Armour Institute, Chicago
Past Secretary, The Aero Club of Illinois
Special Writer and Technical Investigator

EDWARD B. WAITE
Formerly Dean, and Head, Consulting Department, American School of Correspondence
American Society of Mechanical Engineers

WILLIAM C. STIMPSON
Formerly Head Instructor in Foundry Work and Forging, Department of Science and Technology, Pratt Institute

JOHN JERNBERG
Instructor in Forge Practice and Heat Treatment of Steel, Worcester Polytechnic Institute
Member, Swedish Engineering Society

JESSIE M. SHEPHERD, A. B.
Head, Publication Department, American Technical Society

Authorities Consulted

THE editors have freely consulted the standard technical literature of America and Europe in the preparation of these volumes. They desire to express their indebtedness, particularly, to the following eminent authorities, whose well-known treatises should be in the library of everyone interested in Modern Shop Practice.

Grateful acknowledgment is here made also for the invaluable co-operation of the foremost manufacturers and engineering firms, in making these volumes thoroughly representative of the best and latest practice in machine and pattern shops, foundries, and drafting rooms, and in the construction and operation of machine tools, and other classes of modern machinery; also for the valuable drawings and data, suggestions, criticisms, and other courtesies.

C. L. GOODRICH

Department Foreman, Pratt & Whitney Company

Joint Author with F. A. Stanley of "Accurate Tool Work," "Automatic Screw Machines and Tools"

OSCAR E. PERRIGO, M. E.

Consulting Mechanical Engineer

Author of "Modern Machine-Shop Construction, Equipment, and Management"; "Lathe Design, Construction and Operation"; "Change Gear Devices"

JOHN LORD BACON

Formerly Instructor in Forge Work, Lewis Institute, and Instructor in Shop Work, University of Chicago

Author of "Forge Practice"

JOSEPH V. WOODWORTH, M. E.

Author of "American Tool Making," "Punches, Dies, and Tools for Manufacturing in Presses," "Dies, Their Construction and Use for the Modern Working of Sheet Metals," "Gages and Gaging Systems," "Grinding and Lapping," "Drop Forging, Die Sinking and Machine Forming of Steel," etc.

FREDERICK A. HALSEY

Editor Emeritus, *American Machinist*

Author of "Methods of Machine Shop Work," "Handbook for Machine Designers and Draftsmen"

WILLIAM KENT, A. M., M. E.

Consulting Engineer; Formerly Dean of the L. C. Smith College of Applied Science, Syracuse University; Member of the American Society of Mechanical Engineers, etc.

Author of "The Mechanical Engineer's Pocket-Book," "Strength of Materials," "Steam Boiler Economy," etc.

Authorities Consulted—Continued

FRED H. COLVIN

Associate Editor of *American Machinist*
Author of "Machine-Shop Calculations"; Joint Author with F. A. Stanley of "American Machinist's Handbook," "Machine Shop Primer," "Hill Kink Books"; Joint Author with Lucius Haas of "Jigs and Fixtures," etc.

EDWARD R. MARKHAM

Instructor in Shop Work, Harvard University and Rindge Technical School
Consulting Expert in Heat Treatment of Steel
Formerly Superintendent, Waltham Watch Tool Company
American Society of Mechanical Engineers

HARRY HUSE CAMPBELL

Metallurgical Engineer, the Pennsylvania Steel Company
Author of "The Manufacture and Properties of Iron and Steel"

HUGO DIEMER, M. E.

Professor of Industrial Engineering, Pennsylvania State College
Author of "Factory Organization and Administration"; Joint Author with G. H. Resides of "Wood Turning"

F. A. STANLEY

Associate Editor of *American Machinist*
Joint Author with F. H. Colvin of "American Machinist's Handbook," "Machine Shop Primer," and "Hill Kink Books"; Joint Author with C. L. Goodrich of "Accurate Tool Work," "Automatic Screw Machines and Tools"

HENRY M. HOWE, B. S., A. M., LL. D.

Formerly Professor of Metallurgy, Columbia University
Author of "Iron, Steel, and Other Alloys," "Metallurgical Laboratory Notes"

JOSHUA ROSE, M. E.

Author of "Mechanical Drawing Self-Taught," "Modern Steam Engineering," "Steam Boilers," "The Slide Valve," "Pattern Maker's Assistant," "Complete Machinist"

P. S. DINGEY

Associate Member, American Society of Mechanical Engineers
Author of "Machinery Pattern Making"

ROBERT GRIMSHAW, M. E.

Author of "Steam Engine Catechism," "Boiler Catechism," "Locomotive Catechism," "Engine Runner's Catechism," "Shop Kinks," "Saw Filing," etc.

JOSEPH G. HORNER

Associate Member of the Institution of Mechanical Engineers
Author of "Pattern Making," "Hoisting Machinery," "Tools for Machinists and Wood-workers," "Modern Milling Machines," "Engineers' Turning," "Practical Metal Turning," etc.

THOMAS E. FRENCH, M. E.

Professor of Engineering Drawing, Ohio State University
Author of "Engineering Drawing"

WILLIAM JOHN MACQUORN RANKINE, LL. D., F. R. S. S.,

Civil Engineer; Late Regius Professor of Civil Engineering and Mechanics in the University of Glasgow, etc.
Author of "Applied Mechanics," "The Steam Engine," "Civil Engineering," "Useful Rules and Tables," "Machinery and Mill Work," "A Mechanical Textbook"

WALTER LEE CHENEY

Joint Author with Fred H. Colvin of "Machine-Shop Arithmetic," and "Engineer's Arithmetic"

GARDNER C. ANTHONY, A. M., Sc. D.

Professor of Technical Drawing, and Dean of the Department of Engineering, Tufts College, Massachusetts
Author of "Elements of Mechanical Drawing," "Machine Drawing," "The Essentials of Gearing"

CHARLES W. REINHART

Formerly Chief Draftsman, *Engineering News*
Author of "Technic of Mechanical Drafting"

SIMPSON BOLLAND

Author of "The Iron Founder," "The Iron Founder's Supplement," "Encyclopedia of Founding," "Dictionary of Foundry Terms," etc.

THOMAS D. WEST

Practical Moulder and Foundry Manager; Member, American Society of Mechanical Engineers
Author of "American Foundry Practice"

Authorities Consulted—Continued

WILLIAM RIPPER

Professor of Mechanical Engineering in the Sheffield Technical School; Member of the Institute of Mechanical Engineers
Author of "Machine Drawing and Design," "Steam," etc.

OSCAR J. BEALE

Author of "Handbook for Apprenticed Machinists"

JAMES LUKIN, B. A.

Author of "Possibilities of Small Lathes," "Simple Decorative Lathe Work," "Turning for Beginners," "The Lathe and Its Uses," "The Forge and Lathe," etc.

O. M. BECKER

Author of "High Speed Steel—Its Manufacture, Use, and the Machines Required"

F. W. BARROWS

Author of "Practical Pattern Making"

L. ELLIOTT BROOKES

Author of the "Automobile Handbook," "Practical Gas and Oil Engine Handbook," "The Calculation of Horse-Power Made Easy," "20th Century Machine-Shop Practice"

STANLEY H. MOORE

Member or Associate, American Society of Mechanical Engineers, American Institute of Electrical Engineers, Franklin Institute, etc.
Author of "Mechanical Engineering and Machine-Shop Practice"

CHARLES C. ALLEN

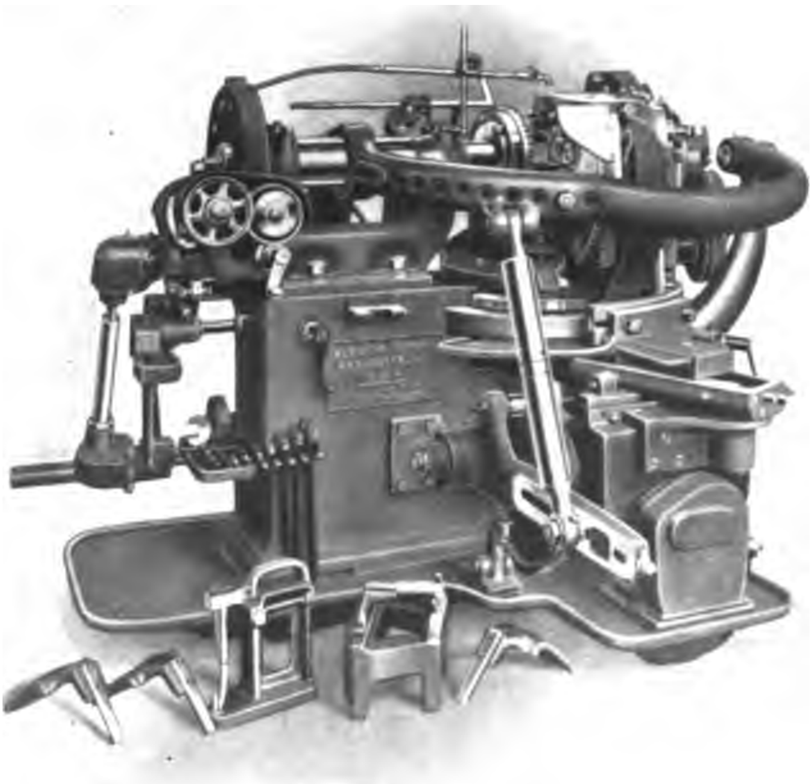
Lecturer in Engineering, Municipal Technical Institute, Coventry, England
Author of "Engineering Workshop Practice"

BRADLEY STOUGHTON

Consulting Engineer; Formerly Adjunct Professor, School of Mines, Columbia University
Author of "The Metallurgy of Iron and Steel"

F. W. TAYLOR, M. E.

Late Member, American Society of Mechanical Engineers
Author of "On the Art of Cutting Metals"



GLEASON ELEVEN-INCH BEVEL GEAR GENERATOR
Courtesy of Gleason Works, Rochester, New York

Foreword

A LITTLE more than a century ago our mechanical development had its beginning when the first prime movers were invented and developed. With the development of machines came the development of mechanics to run these machines, to fabricate the parts and assemble them into the finished articles. The evolution of both machines and mechanics has been marvelous, the accuracy of workmanship of today being easily two hundred times that of a century ago, and the speed of manufacture probably much more than this. Since that time one industry has helped to develop others until today the mines produce ore in large quantities to supply the iron, copper, and other metals; the great steel mills supply the raw or fabricated material; the foundries and forging shops fashion the many castings and forgings for the intricate machine to be built; the immense shops machine the parts and assemble them for the market. Everywhere we turn we find a manufactured article which has gone through these various changes from raw material to finished product.

¶ "Production" methods have enormously increased the output of our shops and the machines which have made this development possible are of a diversified character—speed lathes, planers, multiple drillers, grinders, milling machines, stamping machines, die presses and the jigs, tools and dies which go with them—all of these have contributed to the accuracy and speed of manufacture. The demands of the automobile industry have done wonders in hastening this development as the manufacture of the parts in duplicate was absolutely necessary in order to cheapen the price of the assembled machines. The fact that many of the present-day automobiles

are shipped "knocked down" to assembly points without ever having been put together is an eloquent testimonial to the accuracy with which the duplicate parts are built. Another contributing factor in modern production methods is the development of high speed steels which enable the operators to run the machines at speeds hitherto unattainable.

¶ And yet with all this wonderful development of the machines themselves and the design of what are termed "automatics," the workman has not lost his skill. In fact, one trip to a well-organized scientific machine shop will teach any skeptic that the intelligent workman who has contributed so largely to the mechanical developments of the past twenty years is more skilled, more intelligent, certainly better paid, and more interested in his work than ever.

¶ But this same skilled mechanic is today a specialist. He has no opportunity to build a complete machine or even a small part of one; his active work is carried on along rather narrow lines. Consequently, it is all the more necessary for him to have a standard reference work to help him in other shop lines with which he is unfamiliar. "Modern Shop Practice" is such a work—one which has been tested through six editions—and the practical treatises on the various shop subjects have been supplied by well-known teachers and practical men and are strictly up-to-date. The authors have at all times kept in mind the practical nature of their subjects and numerous shop kinks and other helpful suggestions have been introduced. It is the hope of the publishers that this new edition will supply the needs of both the skilled mechanic and the layman who is interested in mechanical affairs.

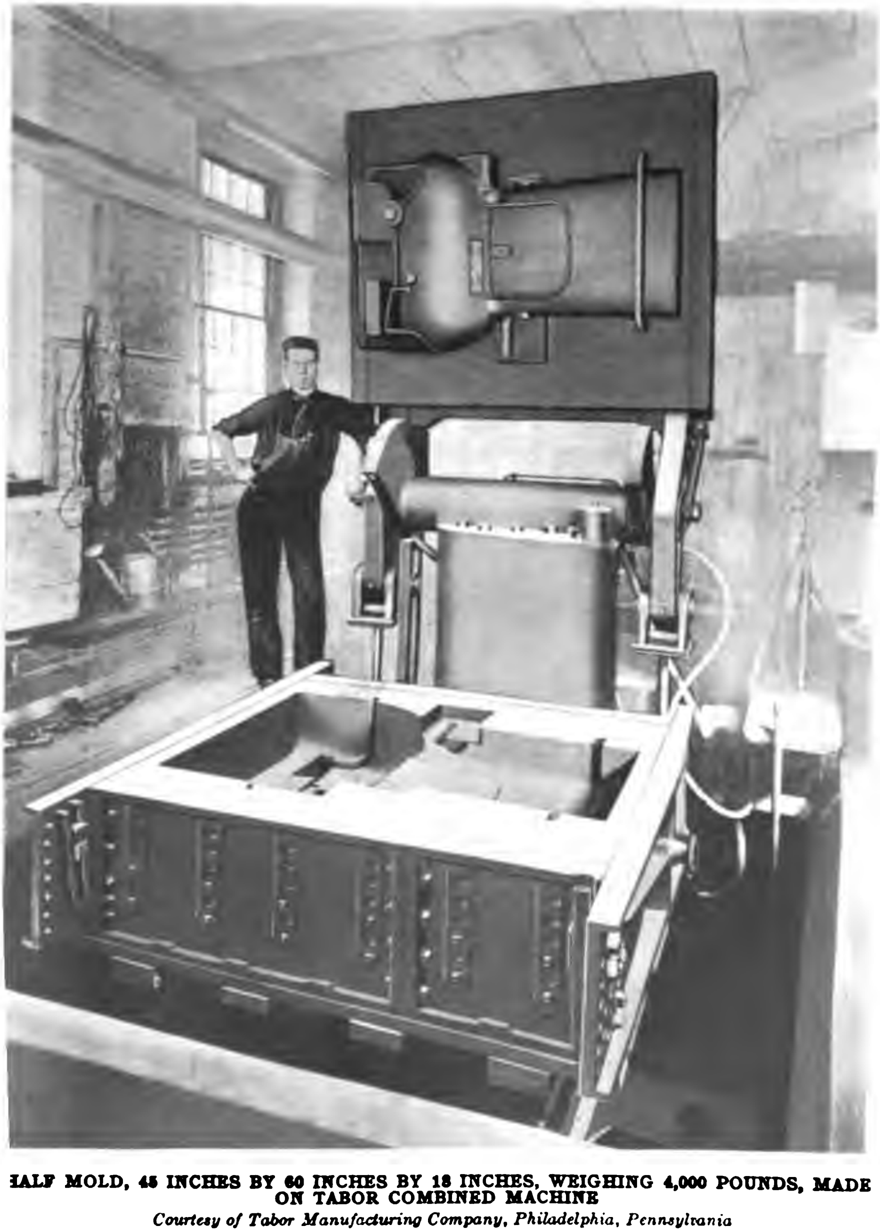
¶ In conclusion, grateful acknowledgment is given to the authors and collaborators — engineers and designers of wide practical experience and teachers of recognized ability—without whose co-operation this work would have been impossible.

Table of Contents

VOLUME V

* For page numbers, see foot of pages.

† For professional standing of authors, see list of Authors and Collaborators at front of volume.



HALF MOLD, 45 INCHES BY 60 INCHES BY 18 INCHES, WEIGHING 4,000 POUNDS, MADE ON TABOR COMBINED MACHINE

Courtesy of Tabor Manufacturing Company, Philadelphia, Pennsylvania

PATTERN MAKING

PART I

PRACTICAL REQUIREMENTS

Characteristics. Pattern making dates back to the time when the first article was made from molten metal for the use of man. The pattern must precede the making of its metal counterpart, and is therefore the first subject to be treated in the working of metal.

Woodworking. The pattern maker is essentially a worker in wood, though, where many castings are to be made from the same pattern, the final or working pattern is made of metal. These metal patterns are very serviceable, and leave the sand more easily and cleanly than those made of wood. Metal patterns are always necessary when the work is of a delicate or very light character. In all such cases, however, the first pattern from which the metal pattern is to be molded is made of wood, allowance being made for double shrinkage, and, when necessary, for double finish. The necessity for this will be clearly explained farther on.

Knowledge of Metals. The pattern maker should possess a practical knowledge of the properties of metals. First of all, he must understand the shrinkage of metals, that is to say, how much smaller the cold casting will be than the molten mass as it flows into the mold; he should know what the strength of the metal is; he should be familiar with the relative rapidity of cooling, so that internal stresses in the body of the completed casting may be avoided as much as possible; he also should know enough about the practical work of the molder to decide upon the peculiarities of construction of the pattern for any given piece.

Drafting and Designing. The pattern maker must be sufficiently skilled as a draftsman to lay out, without the assistance of the designer, the drawings of the piece to be made. This qualification is one of the most important. It is very true, however, that there are many good pattern makers who do not possess all of these qualifications.

The drawings furnished the pattern maker are usually on a small scale. In order to work to the best advantage, he must reproduce a part or all of them at full size, as working drawings. To do this in such a way that the lines and curves of the finished pattern shall be graceful and artistic in appearance requires the same nicety and precision of workmanship that are demanded in the drafting room, and it is essential that the pattern maker have the same complete knowledge of the principles involved. To the extent, then, of being able, when necessary, to make a full-sized drawing of the article to be made, the pattern maker must be a draftsman.

In large establishments, where all the work comes to the pattern shop in the form of carefully executed drawings, the pattern maker is the means of putting the ideas of others into tangible shape. In smaller places, where no draftsman is employed, the pattern maker will be called upon to work out the designs for which he is to make his patterns, and he thus becomes the real designer.

Finally, the pattern maker is seldom required to make two patterns that are identically the same. His work, therefore, is varied, and he must be prepared to apply to the solution of new problems that arise such principles as he may already have learned.

WORKING MEDIUM

Ideal Material. As patterns are subjected to more or less rough usage, and are alternately wet and dry, it follows that the ideal material is one whose hardness is such that it will withstand the wear and tear of handling and at the same time be impervious to the effects of moisture. Such material is to be found in the metals, but, as the cost of working these into the proper shape is considerable, some kind of wood is usually substituted.

Woods Used. *White Pine.* If, then, wood is to be used, another qualification is to be added—namely, it should be easily worked. The best wood for the purpose is undoubtedly white pine. Care should be exercised in the inspection of the wood, to see that it is clear, straight-grained, and free from knots. The straightness of the grain can be determined by the appearance of the sawed face which should present an even roughness over the whole surface.

The wood should be seasoned in the open air, but preferably sheltered by a roof, and should be piled so that the air has free

access to all parts of the plank. In the natural process of air-drying, the moisture slowly works out to the surface and evaporates until the wood is dry or seasoned. One of the characteristics of wood is that moisture is readily given off from its surface if the surrounding atmosphere has a lower humidity, and also readily absorbs moisture in case of being subjected to a higher humidity. In kiln-drying, the stock is robbed of its moisture to a point below that normally contained in outside atmosphere. This means that every time some of the surface stock is removed, exposing a new surface, the stock at this surface will either attempt to absorb moisture and swell, or moisture will dry out, shrinking the stock, and in either case warping and disturbing the stock. This changing is always going on in pattern stock to some degree, but is less in stock that has dried or seasoned naturally to a point where there is about the same amount of moisture in the stock as there is in the atmosphere. It is best to keep the pattern stock for some time before its use as nearly as possible under the same atmospheric conditions as it is in while the pattern is being built. This holds good whether the stock is air- or kiln-seasoned.

It may be stated then, that, in the United States, white pine is the material commonly employed for pattern making. Lumber 1 inch, $1\frac{1}{4}$ inches, and $1\frac{1}{2}$ inches thick will be found convenient in the construction of such patterns as are most commonly called for. It results in a great saving of time and labor, after the lumber has been carefully selected, to have it taken to the planing mill and dressed on two sides to the following thicknesses: 1-inch, dressed on two sides to $\frac{7}{8}$ inch; $1\frac{1}{4}$-inch, dressed on two sides to $1\frac{1}{8}$ inch; $1\frac{1}{2}$-inch, dressed on two sides to $1\frac{3}{8}$ inch; and, if such can be found well-seasoned, a small quantity of 2-inch, dressed to $1\frac{3}{4}$ inches. In addition to these sizes there should be a moderate amount of 1-inch resawed and dressed to $\frac{3}{8}$ inch or to $\frac{5}{16}$ inch; and the same amount of $1\frac{1}{4}$-inch resawed and dressed to $\frac{1}{2}$ inch. The last two thicknesses are used for gluing and building up the rims of pulleys, gear wheels, and other light work, where strength and durability are required.

Hard Woods. Although pine is in general the ideal wood for pattern work, it is soft and weak, so that, if small and strong patterns are desired, a harder wood is usually employed, Mahogany

is much used for this purpose. Like pine, it is not liable to warp, and, when straight-grained, it is worked with comparative ease. There are many varieties of this beautiful wood, varying greatly in firmness of texture. The soft bay wood, often sold as genuine mahogany, should be avoided for patterns, being but little harder than pine. Cherry is also extensively used, but is not so easily worked to a smooth surface as mahogany, and is more liable than the latter to warp and to be affected by moisture. Black walnut, beech, and maple are used to some extent. Black walnut is stronger than cherry, but, like beech and maple, is likely to warp.

Warping of Wood. Observation shows that if one side of a board is kept damp and the other dried, the former will expand so that the plank, although originally straight, becomes curved, as in Fig. 1. Or if one side of a board is exposed to the air, while the other is more or less protected,

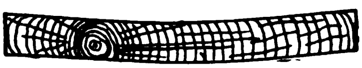


Fig. 1. Board Warped from Unequal Dryness

Fig. 2. Warping of Pile of Boards

as in the stack of boards shown in Fig. 2, the exposed side of the upper board will give off its moisture more rapidly than the other side, and the board will warp or bend in the direction shown by the dotted lines. The second board will also draw up and to some extent follow the first, being in turn followed by the third, and so on until the entire stack is warped and bent.

The same thing will be found true of a well-seasoned board if after being planed it is allowed to lie on its side on the work bench. The upper side will give off its moisture more freely than is possible for the under side, the latter being protected and having its moisture retained by the bench. The lower side of the board is thus caused to expand, and the upper to contract, with the result that the board, although originally planed straight, becomes curved. For this reason all lumber, even if well-seasoned, should be so placed in racks, or on end, that the air may have free access to both sides of the planks; and newly planed boards, however dry and well-seasoned, should never be stacked together, but so placed that both sides will be exposed alike.

This tendency to warp is explained to some extent by the porous nature of all woods, and their inclination to give off or to absorb moisture according to the condition of the surrounding atmosphere. As there is always more or less moisture in the air, and lumber of all kinds contains an amount of moisture which is ever changing according to the conditions of the surrounding atmosphere, this causes corresponding expansion or contraction of the wood.

Even under cover and in a dry place, wood has a tendency to warp on account of the greater shrinkage of the newer as compared with the older cells of the wood tissue or fiber in the side of the board nearest to the outside or sap wood of the tree. The inner side *A* of the board, Fig. 3, being closer to the heart wood, is older than the side *B*, and its cells are firmer and more compact than those of *B*. As the board seasons, the newer and more open cells of the side *B* shrink faster and to a

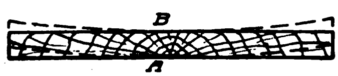


Fig. 3. Effect of Older Fibers in Warping

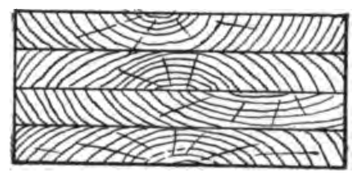


Fig. 4. Reversing Layers in Building Up

greater extent than those of *A*, thus causing the board to draw or warp in the direction indicated by the dotted lines.

Correction by Reversing Grain. In gluing or building up stock for a pattern, this tendency may be corrected to some extent by reversing the grain of the pieces that are to be glued, and placing together two outsides, as *B*, or two insides, as *A*, Fig. 3. This is fully illustrated in Fig. 4.

In gluing very thin pieces together for the webs or centers of pulleys and for other purposes, it is often necessary to reverse the grain of the pieces, or to place the grain of one piece at right angles to that of the other, for the purpose of gaining greater strength and stiffness. In such cases, if only two thin pieces are used, the result, to some extent, after they have been glued and dried, is as shown in Fig. 5, the shrinkage and strain of the end grain crosswise of the board at *a*, being sufficient to bend the opposing thin board lengthwise of the grain at *b*, while on the side *c d*, the curve is reversed for the same reason. Whenever it is necessary to cross the grain of thin

pieces for a pattern, three or more pieces should be used, which will give satisfactory results if placed together, as shown in Fig. 6.

Fig. 5. Warping of Two Thin Pieces

When thin circular disks of large size are to be glued up for patterns of any kind, the strongest, stiffest, and most satisfactory results will be obtained if the pieces are fitted and glued tangentially to the hub or other center or opening in the disk, as shown in Fig. 7. The grain of the wood must run lengthwise, and parallel to the longest side of each sector; and, after the pieces have been fitted together, a thin groove is cut in the edge of each, in which thin tongues of wood are inserted and glued, as illustrated in Fig. 8. Two disks are glued up, and one is turned over so as to reverse the grain of the sectors of one disk on that of the other, as shown by the dotted lines. The disks are then glued together, making a very rigid construction, and one which, owing to the continual change in the direction of the grain, will not warp.

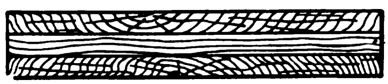


Fig. 6. Flatness Obtained by Crossing Grain of Three Thin Pieces

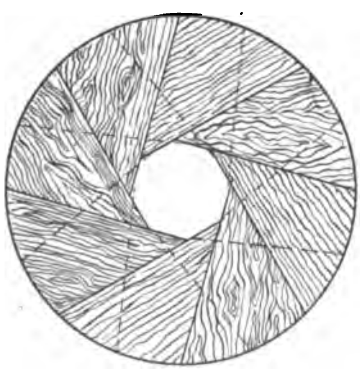


Fig. 7. Tangential Graining

Fig. 8. Interlocking Tongues

Should a wide and thin piece of a single thickness be required for a pattern, the board from which it is to be made should be ripped into strips of 2-, 3-, or 4-inch width—according to the width of the required board—and the strips glued together again with each alternate strip reversed, as shown in Fig. 9. In this way warping is largely corrected, each narrow strip being inclined to warp in an opposite direction to that of its neighbor.

TOOL EQUIPMENT

Distinction in Use. While many of the tools used by the pattern maker are identical with those used by the carpenter and cabinetmaker, yet the conditions which govern the construction of patterns for the molding of metals, together with the required accuracy in dimensions, and the methods of construction used to guard against warping, distortion, and breaking, have very little in common with the workmanship and methods of the carpenter, the wood turner, or the cabinetmaker.

Fig. 9. Reversed Grain of Strips for Wide Stock

Following is a descriptive list of the more essential tools used in pattern making, accompanied with instructions in their use.

HAND CUTTING TOOLS

Rip Saw. Hand saws are of two kinds—rip, and crosscut. The former, as the name indicates, is for cutting with the grain, or lengthwise of the board to be sawed. In Fig. 10 is illustrated a rip saw having 5½ points to the inch, which will work rapidly and with ease in pine and other soft woods. If mahogany, cherry, or other hard wood is to be ripped, a 6-point saw should be used.

Hook of Teeth. Rip saws should be filed with all the bevel on the back of the tooth, as shown at *b* in Fig. 10, the front or throat of the tooth being at right angles to, or square with, the tooth edge of the blade, as at *a*. The position of the line *cd*, whether perpendicular or slanting, is called the *hook* or pitch of the tooth.

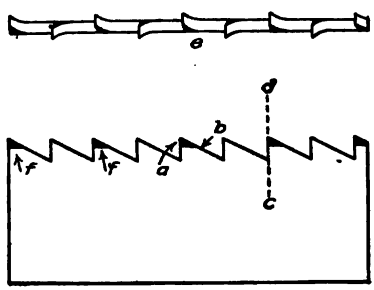


Fig. 10. Teeth of Rip Saw

Filing and Setting. Rip saws should be filed square across; that is, the file should be held horizontal and at right angles to the side of the blade, always filing each alternate tooth from the opposite side of the saw; this, if done by beginning at the heel and working the file toward the point of the saw blade, gives a very slight bevel to the back edge of the tooth, causing it to cut cleaner and to require less set than if filed otherwise.

Rip saws require very little set for use in dry well-seasoned lumber, such as is always used in pattern making. The teeth should be set, or bent, only at the points, as shown at *e* and *f* in Fig. 10—in no case should the set exceed more than half the depth of the tooth. When the points only are set, the saw works more freely, and the blade of the saw is not sprung or bent in setting.

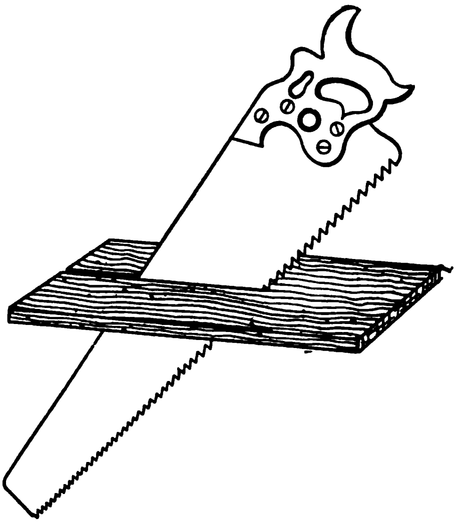


Fig. 11. Position in Ripping

In using a rip saw, the front or cutting edge of the saw blade should be held at an angle of about 45 degrees to the board, as shown in Fig. 11. This brings the back of the tooth nearly at right angles to the fibers of the wood, and insures a shearing cut. For fine work and well-seasoned material, hand saws may be bought ground so thin on the back as to require no set. Such tools work very smoothly and easily, cutting away less wood and doing better work than saws that have been set.

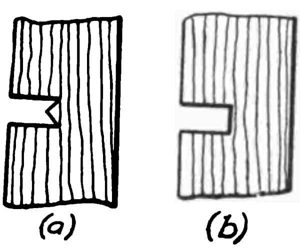


Fig. 12. Kerf Made by Crosscut Saw

Crosscut Saw. The crosscut saw really severs or cuts the fibers of the wood twice, as shown at *a* in Fig. 12, the intervening projections being loosened and carried out as dust by the thrust of the saw, producing a nearly straight-bottomed kerf, as shown at *b*.

A crosscut saw for ordinary work should have 5 or 6 points to the inch; but for fine work 10 or 12 points would be better, especially for dry woods, either soft or hard. A section of a 6-point crosscut saw is shown in Fig. 13, and one of a 13½-point in Fig. 14.

Shape of Teeth. We find that while the rake or tooth bevel in rip saws is all on the back of the tooth, the rake in crosscut saws is

on the side of the tooth, as shown at *a*, Fig. 13. In ripping, the point of the tooth acts as a chisel, cutting off the fibers of the wood, each tooth chiseling off a shaving as it passes through the board; but in crosscutting, the side of the tooth does the cutting, and therefore must have its bevel on the side.

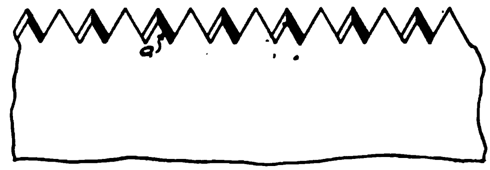


Fig. 13. Crosscut Saw Teeth

In Fig. 13 the *fleam*—angle of the tooth with the plane of the saw blade—is about 45 degrees, and, as shown, there is no hook or pitch, the vertical angles being the same both front and back of the tooth. This form of tooth works well in wet or in very soft wood; but for wood that is well seasoned, and for all the harder woods, the pitch, or vertical angle or inclination, of the front of the tooth should be about 60 degrees to the tooth edge of the blade, as shown at *b*, Fig. 15. The amount of pitch in the teeth of a saw may be varied for different purposes or for different woods, but should be such as to loosen and carry out the intervening wood. Otherwise this would have to be rasped or filed out by the continued action of the saw.

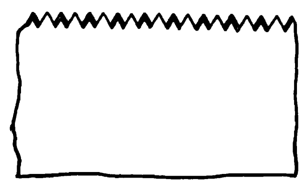


Fig. 14. Crosscut Teeth for Fine Work

Filing. The fleam or horizontal angle of the side of the crosscut saw tooth is very important. When filing, the file should be held horizontally and at an angle of about 45 degrees to the side of the saw, lengthwise of the blade, as illustrated in Fig. 15, and each alternate tooth must be filed from the opposite side of the blade, beginning at the heel and filing toward the point of the saw.

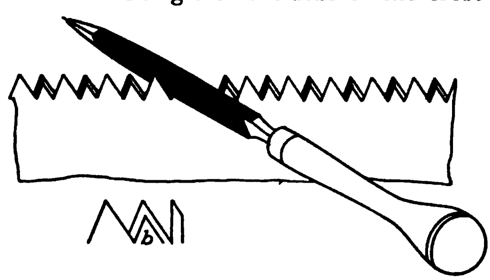


Fig. 15. Filing Crosscut Teeth

The objection is often raised by saw filers, that, in filing from the handle end of the saw toward the point, a feather edge is made by the file and turned backward on the point of the tooth. The

first thrust of the saw through the board, however, will remove this featheredge entirely; whereas, if the filing is done from the point of the saw toward the handle, it is necessary to file the teeth bent toward the operator, which causes the saw to vibrate, or chatter, and this not only renders good even filing impossible, but breaks the teeth of the file.

Setting. For hand and back saws, a saw set that acts on the principle of the hammer and anvil, such as the one illustrated in Fig. 16, is best. The spring sets, so much in use, will not give so regular and even a set to the teeth as will one or more light blows with the hammer on the beveled face of the anvil. By this method the tooth is not bent or sprung beyond the position in which it is intended to remain, and the blade of the saw is not bent or affected by the stroke of the hammer on the point of the tooth. A saw set, of the kind shown in Fig. 16, can be adjusted to set the points of the teeth to any depth desired; and, even if repeated light blows are given, the tooth cannot be bent beyond the required distance. The blow may be struck on *a* with a light mallet or it may be struck from below with the operator's foot on a treadle connected with *e*, leaving both hands free to hold and to guide the saw.

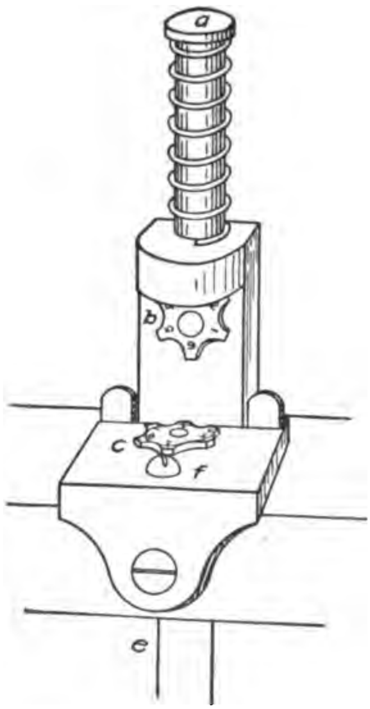


Fig. 16. Saw Setter

In setting a saw, it is always better to use two or three light blows on a tooth than to try to do the work with one heavy blow; and this is especially the case if the saw is hard, as all good and well-tempered saws should be.

Back Saw. The back saw illustrated in Fig. 17 is used as a bench saw for light or fine work, and for fitting and dovetailing. Saws of this type are made from 8 to 14 inches in length, the 10- and

12-inch being convenient sizes for general work. As the metal back holds and stiffens the saw, a thin blade should always be selected. The methods of filing, jointing, and setting are the same as those described for the other hand saws. At least two back saws will be found necessary, one filed for crosscutting, and the other filed as a rip saw for cutting with the grain of the wood, as in the cutting of tenons and dovetails.

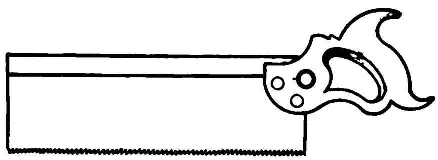


Fig. 17. Back Saw

Exercise. While for those who have had experience in carpentry the following exercise in the use of the back saw may not be necessary, it is recommended to all beginners who wish to acquire skill in the use of this important tool.

Take any block of wood from 12 inches to 16 inches long, about 2 inches wide, and about 1¾ inches in thickness. With try-square and a sharp-pointed pocketknife, lay it out, as illustrated in Fig. 18, on the upper, front, and back sides of the block. The knife cuts must be at least $\frac{1}{16}$ inch deep, and about ¼ inch distant from each other. Next proceed to saw up the block into thin sections, sawing each time so that the saw kerf will be just outside of, but close to the knife line, as indicated at *a*.

The saw cut through the block should be true to each of the three lines; and while the saw passes along one side of the line, its teeth should not scratch the opposite side of the knife cut, but should leave a smooth clean angle of the knife cut on the block, as shown at *b* in Fig. 18, while at the same time it should be so close to the line as to leave no wood to be smoothed off with plane or chisel.

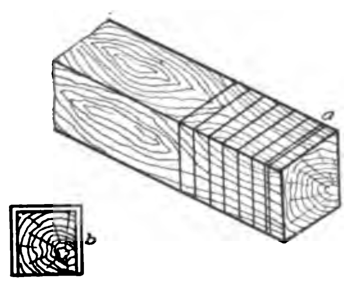


Fig. 18. Example of Back Sawing

A few hours' thorough and careful practice of this exercise will enable any one to use the saw successfully.

Compass Saw. As the work of the compass saw, Fig. 19, is both with and across the grain of the wood, the best form of tooth is that shown in Fig. 20, having more pitch, and slightly less bevel, than the crosscut saw. A crosscut saw will rip better than a rip saw will crosscut; hence the shape of tooth should be between the two. Compass saws are

ground very thin on the back of the blade, but in order to turn easily they should be set the same as hand saws.

And here we wish to impress on the beginner the necessity of keeping his saw—and, indeed, all other cutting tools—perfectly

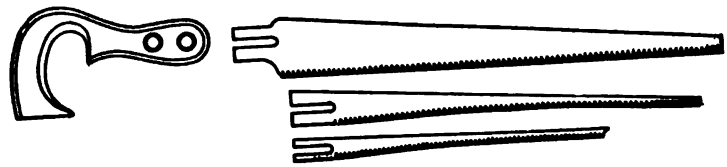


Fig. 19. Compass Saw

sharp and in good working condition at all times. A sharp saw works faster, and always does smoother and better work with less set and with less expenditure of power, than a dull one. Even to saw well is an art, which cannot be gained through the use of dull, imperfectly set, and poorly kept tools. To file well will require from the beginner close attention, a study of the subject, and careful practice, all of which can be given by any one possessing ordinary mechanical ability. If the filing is done slowly at first, care being taken to hold the file at the same angle for all the teeth, a little faithful practice will always bring success.

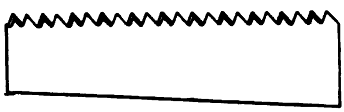


Fig. 20. Compass Saw Teeth

Iron Plane. The modern iron plane, illustrated in Fig. 21, can now be bought in a great variety of sizes and styles. These planes, with their true and unchanging faces, and their simple appliances for setting and adjusting the cutter, or plane iron, to the face of the plane and to the required thickness of shavings, are greatly to be preferred to the old-style wooden planes.

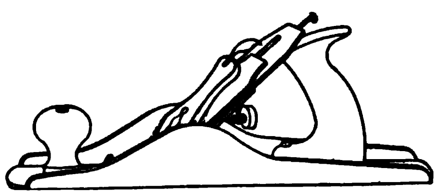


Fig. 21. Iron Plane

Construction. The general construction of the iron plane will be readily understood from Fig. 22, one side of the plane being removed to show the arrangement of the parts. The cutter, or plane iron a is made of the best cast steel, and is of equal thickness through-

out; in all new planes this part will be found ground and sharpened for immediate use. The cap iron *f*, Fig. 22, is fastened to the plane iron by an adjusting screw, as shown in Fig. 23. For whetting or grinding the cutting edge, it is not necessary to remove the cap iron, but only to loosen the connecting screw and to slide the cap back to the extreme end of the slot in the plane iron, tightening it there by a turn of the screw. The cap iron will then serve as a convenient handle or rest for the workman in whetting or grinding the blade.

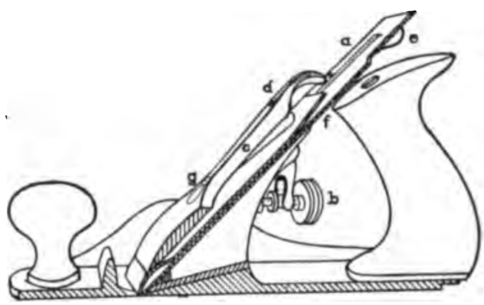


Fig. 22. Section of Plane

The iron lever *c*, Fig. 22, is held in place below its center by the screw *g*, which acts as a fulcrum, and the lever is readily clamped down upon the irons by the use of the cam piece *d*. When this cam is turned upward it ceases to bear upon the irons, and the lever *c* may then be removed from its place, and the irons released, without turning or changing the adjustment of the screw *g*, as the lever and irons are properly slotted for this purpose. Should the pressure required for the best working of the plane iron need changing, it can easily be obtained by tightening or loosening the screw *g*.

When the plane iron is secured in its place, the use of the brass thumb screw *b* will draw or drive the plane iron, and thus the thickness of the shaving to be taken from the work can be regulated with perfect accuracy. By the use of the lever *e*, located under the plane iron and working sidewise, the cutting edge can easily be brought

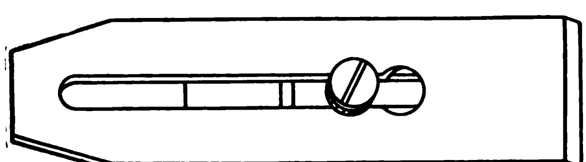


Fig. 23. Plane Iron—Cap Iron Connection

into position exactly parallel with the face of the plane, should any variation exist when the iron is clamped down. To ascertain this, hold the plane up, and look down over its face; the greater projection, if there is any, of one or the other of the corners of the iron, can readily be seen.

The cap iron *f*, which is not sharp, is not used for the purpose of strengthening or stiffening the cutting iron, as is often supposed, but as a chip break to prevent the cutting edge of the plane iron from chipping, tearing, and breaking the grain of the wood below the surface when the grain turns and twists, or when it is knotty and crooked. In such cases the tendency of the plane iron is to split and tear out the fibers of the wood in front of the cutting edge. To avoid this, the cap iron is screwed on, with its dull edge quite close to the cutting edge, so as to bend and break off the fibers or the shavings before the split gets fairly started below the surface.

The cutting edge of the plane iron is said to have lead in proportion to the distance it is placed in advance of the dull edge of the cap iron. The depth of the splits, or the roughness of the cross-grained surface, will be just equal to the lead of the cutting edge. For soft straight-grained wood the lead may be $\frac{1}{32}$ inch or even more, but this must be reduced in proportion as the wood is curly, cross-grained, or knotty.

Grinding. The grinding, or the whetting, must always be done on the bevel side only of the plane iron, the upper side being kept as flat and as smooth as possible to secure easy working.

All plane irons should be ground slightly rounding to the extent of the thickness of a thin shaving. This rounding of the cutting edge should be the true arc of a circle throughout the entire length of the cutting edge, and not simply a rounding-off of the corners as is sometimes directed. Rounding the edge to the extent of the thickness of a shaving prevents the plane iron from grooving into, or plowing out a wide groove in the surface that is being worked, and also assists greatly in working the edges of the piece to right angles, or square with the face side. To do this, it is not necessary, should one corner of the edge be higher than the other, to tilt the plane on the high edge, but, while holding it flat and firm on the surface of the edge being planed, the plane should be pushed side-

wise toward the highest corner in order to reduce that corner. This is readily understood when we remember that the cutting edge of the iron is rounding. If the plane is held so that the middle of the plane iron does the cutting, the shaving planed is of the same thickness on both edges; but if the plane is pushed over to one side, either to the right or to the left, the shaving will be featheredged, or thick on one edge and thin on the other, thus reducing the higher corner of the edge of the piece.

Proper Use. When the plane is to be used, the beginner should first carefully adjust it to the thickness of shaving required by moving the adjusting screw in the proper direction, at the same time holding it up and looking down over the face of the plane, when the projection of the plane iron can readily be seen. The cut should also be tested by trying it on the piece to be planed until the plane is ready for use.

The operator's position should be one of perfect ease, standing well back of the piece to be planed, and pushing the plane to arm's length from, not alongside of, the operator, taking long and continued shavings from the board. When starting the shaving at the end of the board, care should be taken to hold the forward end of the plane down firmly, or the act of pushing it forward will cause that end to tilt up and the plane iron to chatter on the surface as it begins to cut the shaving. This is due to the fact that nearly two-thirds of the plane overhangs the end of the board, requiring firm pressure on the forward end to balance it while the stroke is being started.

To insure smooth work, care must be taken to plane with the grain of the wood, and not against the ends of the fibers as they lie in the surface of the board. Should the fibers tear out and the surface become rough, reverse the ends of the boards so as to cut the shaving in the opposite direction, and note the difference in the effect on the planed surface.

Common Types of Planes. *Jack Plane.* Of iron planes, the most important is the No. 5 jack plane, 14 inches long, and having a cutter 2 inches in width, as illustrated in Fig. 24. When the pattern lumber has first been roughly planed in a planing mill, this No. 5 plane can be used almost exclusively for planing and pattern making.

Jointer Plane. In making or in truing up very large surfaces, or in making long glue joints, the No. 7 jointer plane, 22 inches long and having a cutter $2\frac{3}{8}$ inches wide, will be found necessary. This plane is shown in Fig. 21, and differs from the jack plane only in its length and in its extra width of face.

Smooth Plane. For mahogany or other hard wood, the No. 4 smooth plane, illustrated in Fig. 25, will be found very useful. This

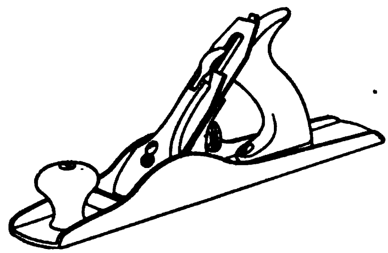


Fig. 24. Jack Plane

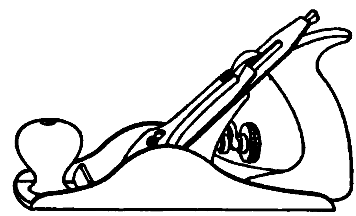


Fig. 25. Smooth Plane

plane is made in several sizes. The No. 4, which is 9 inches long and has a 2-inch cutter, is the best size for general use, particularly for smooth surfaces.

Block Plane. Next in importance to the three planes already mentioned, is the block plane, illustrated in Fig. 26. The No. 19, which is 7 inches long and has a cutter $1\frac{3}{4}$ inches wide, is the most desirable for the pattern maker's use. It has an adjustable throat, as well as the screw and lateral lever adjustments of the other planes.

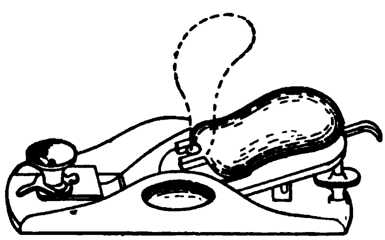


Fig. 26. Block Plane

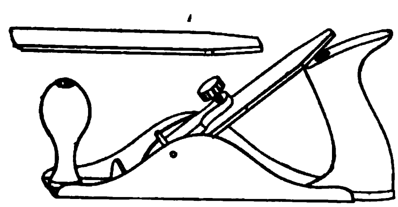


Fig. 27. Scrub Plane

This plane has the advantage of being so constructed as to be held easily in one hand, a fact which makes it especially adaptable for for short work. Owing to the low angle at which the cutter is placed, it works more smoothly and easily on end wood and on miters than any other plane.

Scrub Plane. In cases where lumber must be dressed from the rough, without being first roughly dressed in a planing mill, the No. 40 scrub plane, illustrated in Fig. 27, will be almost indispensable. It is 9½ inches long, and has a cutter 1¼ inches wide. The cutter is a single iron, and is ground and sharpened very rounding on the cutting edge, as shown in Fig. 27, to allow of cutting a very thick shaving without grooving at the edges. This plane works rapidly and easily, preparing the rough-sawn surfaces of planks for the finishing planes.

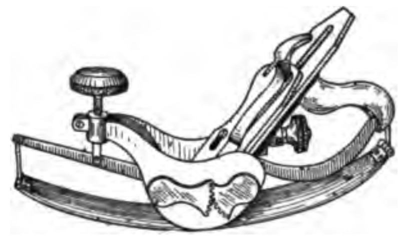


Fig. 28. Circular Plane

Circular Plane. For truing and smoothing circular arcs and curves of all kinds, either convex or concave, there is no tool that equals the circular plane, illustrated in Fig. 28. This plane has a flexible steel face which can easily be shaped to any required arc or curve by turning the knob on the front of the plane.

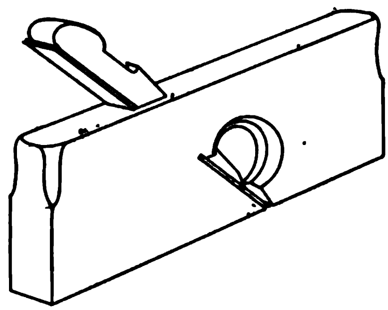


Fig. 29. Rabbet Plane

Special Planes. *Rabbet Plane.* Among the special planes used by the pattern maker, the rabbet plane, llustrated in Fig. 29, is the most important. The face of this plane is always flat and at right angles to the sides. It is used in working out square angles and corners, or *laps* as they are called in carpentry, and also for working the lap joints, as shown in Fig. 30.

Fig. 30. Rabbeted Lap Joint

The skew-iron rabbet plane, in which the cutting edge of the plane iron is set diagonally across the face of the plane, works much more smoothly and easily than one in which the iron is set at right angles to the side of the plane. The improved rabbet plane shown in Fig. 31 is fitted with depth gâge, and also with a spur cutter, both of which are often of great convenience to the workman.

Rabbet planes are made in sizes ranging from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches in width. The 1-inch and $1\frac{1}{4}$-inch are convenient sizes for general work.

Round and Hollow Planes. These planes are illustrated in Figs. 32 and 33. They are made of different curvatures, and a set of assorted sizes, especially the rounds, are almost indispensable to the pattern maker for finishing semicircular core boxes, for making fillets, and for working out curves of every description, both concave and convex.

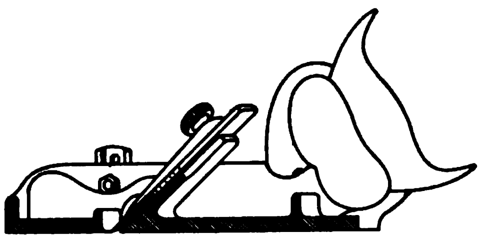


Fig. 31. Improved Rabbet Plane

Core-Box Plane. The core-box plane, shown in Fig. 34, while not indispensable, will be found to be a very rapid working and useful tool for making semicircular core boxes up to $2\frac{1}{2}$ inches in diameter. By using the extension sides, one of which is shown in the illustration, and two pairs of which are always furnished, this

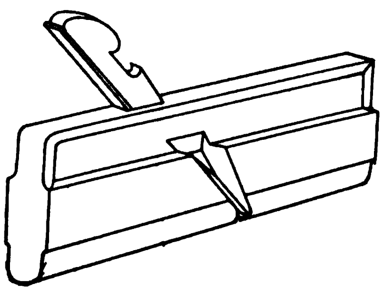


Fig. 32. Round Plane

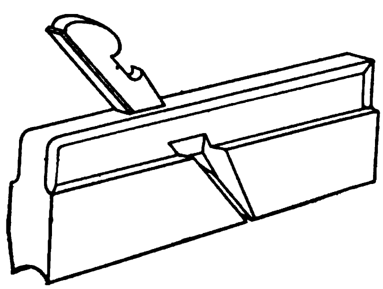


Fig. 33. Hollow Plane

tool will work accurately a concave semicircle up to 10 inches in diameter.

The core-box plane is constructed upon the principle that if the sides of a right angle lie upon the extremities of the diameter of a circle, the vertex of the right angle will lie upon the circumference of the circle. This is illustrated in Fig. 35, from which it will be seen that if the block of wood has been worked to a perfect semicircle, and the edges of the blades of a try-square or right-angled triangle

touch the semicircular curve at its extremities, the right angle or corner will touch the arc at some point, as *b*, *e*, or *h*, and the angles *abc*, *def*, and *ghi* will all be right angles.

To this kind of plane the objection is often made that it abrades and wears off the corners of the semicircle as it is being worked out. This, however, can be practically avoided if the following instructions are put into effect:

Carefully lay out the block from which the core box is to be

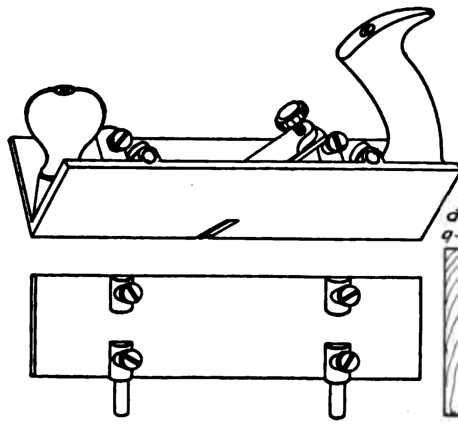


Fig. 34. Core-Box Plane

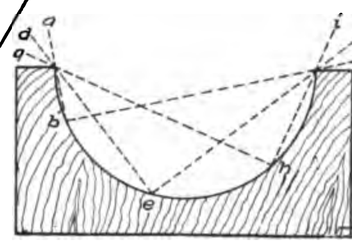


Fig. 35. Profile Cut by Core-Box Plane

worked, from a center line on the face of the block, describing on each end of the block a semicircle of the required radius; connect the extremes of the two end arcs by straight lines on the face of the block, as shown in Fig. 36. Two very thin strips of hard wood are tacked along these lines, just outside of the wood to be cut away, as shown at *a* and at *b* in Fig. 37. These strips form rests for the sides of the plane while the heavier part of the work is being done. After working

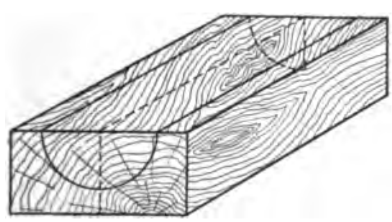


Fig. 36. Block Laid Out for Core-Box

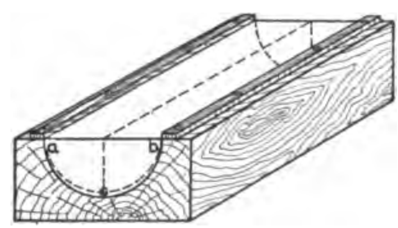


Fig. 37. Protection of Edges in Forming

out the semicircle as far as the strips will allow, as shown by the dotted arc *acb*, the strips are removed, when the work can be finished without materially affecting the corners at *a* and *b*.

When making the finishing cuts with this plane, care must be taken to adjust the cutter centrally, i.e., so that it will cut equally

to both right and left; otherwise the work will not be correct. If, however, the work has been done with care, the finishing may be completed with coarse, and lastly with fine, sandpaper held on a cylindrical block of radius slightly less than that of the required core box.

Router Plane. This tool, illustrated in Fig. 38, will be found very convenient for smoothing out sunken panels, for letting in rapping and lifting plates, and for all depressions below the general surface of the pattern. It will plane the bottoms of recesses to a uniform depth from the surface of the work, and will work into angles and corners that otherwise could be reached only by the use of the paring chisel.

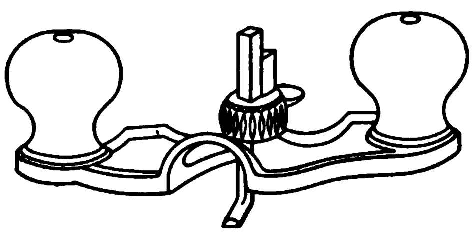


Fig. 38. Router Plane

Spokeshave. The spokeshave is used by the pattern maker for shaping and rounding out small curves, either convex or concave, which cannot be reached with the circular plane. It can be found in a great variety of styles, either in metal, as shown in Fig. 39, or in wood. The all-wood boxwood spokeshave illustrated

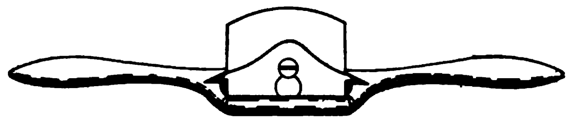


Fig. 39. Iron Spokeshave

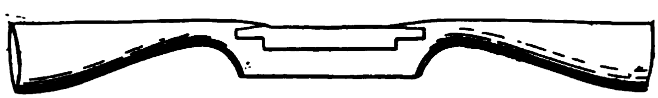


Fig. 40. Wooden Spokeshave

in Fig. 40, without brass facing or screw adjustment, is to be preferred to all others for the pattern maker's use, especially for working pine or other soft wood.

Chisels. The chisel enters so largely into the work of the pattern maker in paring and shaping patterns that the quality of the tool

should be of the best. While carpenters' chisels are made in several styles, they may be divided into two general classes: socket-handled chisels; and firmer or paring chisels. The former are illustrated in Fig. 41, and are used for framing, and for very heavy work of all kinds in which the use of a mallet is necessary.

Common Paring Type. The common firmer or paring chisels, two styles of which are shown in Fig. 42, are the best all-around

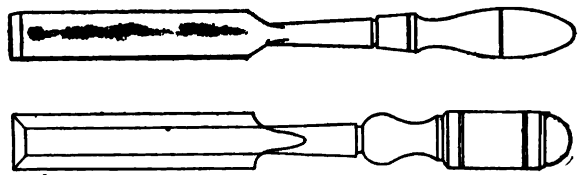


Fig. 41. Socket-Handled Chisels

chisels for pattern work. Being lighter and thinner than the others, they are better adapted to the light work on which they are used; moreover, when used with care, they will answer every desired purpose, even for heavy work or with a mallet. The beveled-edge chisel shown at *a*, Fig. 42, is greatly to be preferred. It is lighter than the other kind illustrated, and, the square angle being removed,

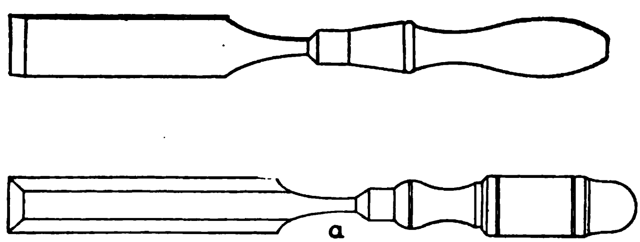


Fig. 42. Paring Chisels

the workman is enabled to reach into angles and under projections difficult to reach with a square-edged tool. A set varying in width from $\frac{1}{8}$ inch to $\frac{5}{8}$ inch by eighths, and from $\frac{3}{4}$ inch to $1\frac{1}{2}$ inches by quarters, nine chisels in all, will be found useful.

Examples of Use. The manner in which the chisel is used is so obvious and simple that any instruction in that direction would seem unnecessary. We shall only say in a general way that, in using

a chisel on a flat surface or in a recess, it should always be held with the flat or back of the chisel against the work, and, whenever possible,

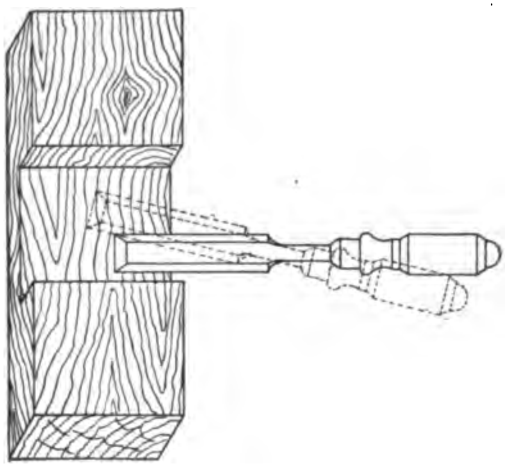


Fig. 43. Method of Using Chisel

it should not be pushed straight forward or straight through an opening, especially when paring across the grain of the wood, but should be moved laterally at the same time that it is pushed forward, as indicated by the dotted lines in Fig. 43. This insures a shearing cut, which, with care, even when the material is cross-grained, will produce a smooth and even surface.

As an exercise for acquiring the free use of the paring chisel, there is nothing better for the beginner than the simple half-lap joint shown in Fig. 44.

Fig. 44. Half-Lap Joint

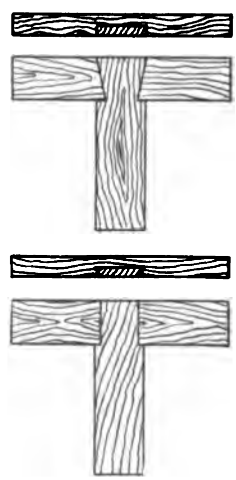


Fig. 45. Dovetail Joints

The shoulders or the ends of the openings must be cut with a back saw. The opening is then cut out and the shoulders

smoothed with a wide chisel, and a perfect fit obtained by continued trials.

The two dovetail joints, shown in Fig. 45, may be attempted after having succeeded with the halflap; and these exercises should be continued by the student until such control of the chisel is attained that this and similar work can be done with ease and certainty. For laying out work of this kind the blade of a pocket-knife or bench knife should always be used. This gives a clean sharp cut angle for the meeting sides of the joints, which cannot be obtained if a scratch awl is used. The awl tears and breaks the fibers of the wood, producing a rough ragged angle, which, on fitting, cannot produce a smooth and close piece of work. A pencil is equally objectionable because of the indefinite dimensions given by its use.

Gouges. The paring gouges used in pattern making are ground or beveled on the inside, as shown in Fig. 46. These gouges

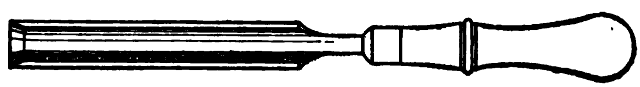


Fig. 46. Paring Gouge

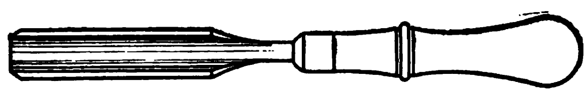


Fig. 47. Common Firmer Gouge

are made in regular, middle, and flat sweeps. They are indispensable for working out core boxes and other curves.

In selecting a set of paring gouges, they should be not only of assorted sizes, but of different sweeps, so as to work out semicircles and curves of different radii.

The common firmer gouge, illustrated in Fig. 47, is a useful tool for rough or heavy work, but in general its use can be dispensed with in pattern making.

Front Bent Type. An assortment of four to nine carver's gouges, front bent, as shown in Fig. 48, will be found necessary for working out short deep curves, and in places where a straight gouge cannot

be used, as in the core boxes for a globe valve—shown in Pattern Making Part II, Figs. 233 and 234—and for similar work.

The full set consists of nine tools, the curves of which are numbered from *24* to *32*. The two extremes, Nos. *24* and *32*, are

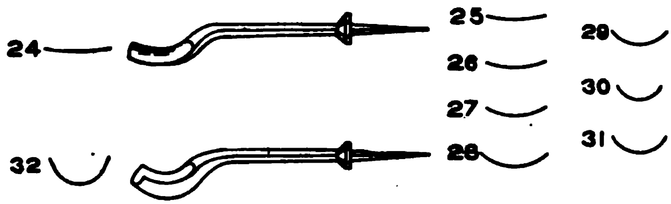


Fig. 48. Carver's Gouges

shown in Fig. 48, and also the shapes of the curves of the seven intermediate, Nos. *25* to *31*, inclusive. If desired, to save expense, each alternate tool might be omitted from the set, only the odd numbers *25*, *27*, *29*, and *31* being selected, and for ordinary work these will be found sufficient.

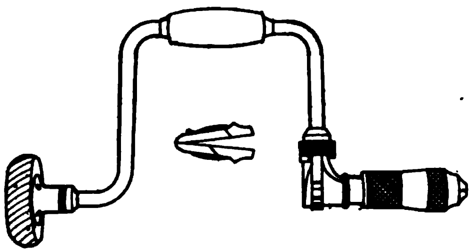


Fig. 49. Ratchet Brace

Boring Tools. *Brace.* Among the necessary tools are the brace and an assortment of boring bits. The most desirable style of brace is the ratchet brace, illustrated in Fig. 49. The con-

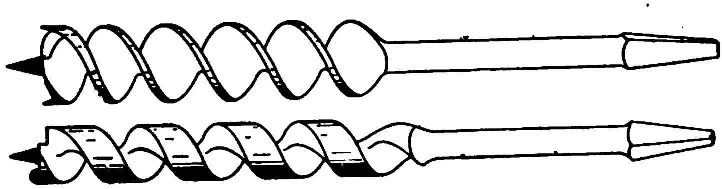


Fig. 50. Auger Bits

venience of the ratchet will soon be apparent from the necessity, so often arising, for boring holes or driving screws in angles or close to projections where the full sweep of the brace cannot be taken. Braces are made in many sizes, with sweeps varying from 6 inches to 14 inches in diameter.

A brace with an 8-inch sweep is the most convenient in size for boring holes 1 inch or less in diameter in soft wood. For larger

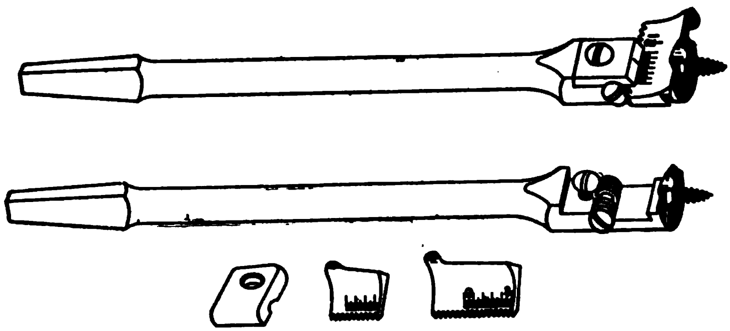


Fig. 51. Extension Bit

holes, and especially in very hard woods, a 10-inch or 12-inch sweep is necessary.

Bits. Wood-boring bits are made in many styles. The most important are the auger bits, two styles of which are shown in

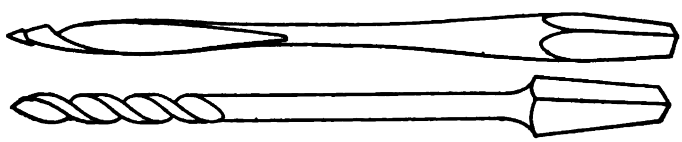


Fig. 52. Gimlet and Wood Drill

Fig. 50. They can be bought in sizes running by sixteenths of an inch from $\frac{3}{16}$ inch to 1 inch. For holes larger than 1 inch, the No. 2 extension bit, shown in Fig. 51, is the best. It has two cutters, and will bore a hole of any size from $\frac{7}{8}$ inch to 3 inches in diameter.

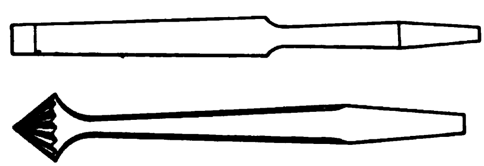


Fig. 53. Brace Screwdriver and Countersink

For screw holes, the gimlet bit or the twist drill for wood, both of which are illustrated in Fig. 52, are used. They can be bought in all sizes running by thirty-seconds of an inch from $\frac{1}{32}$ inch up to $\frac{3}{8}$ inch.

The brace screwdriver, and also the brace countersink for screw heads, are important tools. They are shown in Fig. 53, and can be bought in large, medium, and small sizes.

MEASURING TOOLS

Squares. The best try-squares are now made with blades graduated, and from 2 inches to 12 inches in length. Several sizes of the fixed-blade type, Fig. 54, are needed, as in many cases the blade must be short to admit of its application in pattern work.

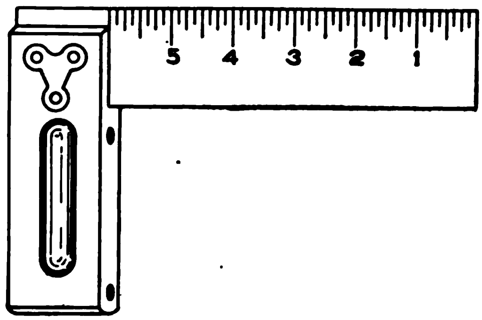


Fig. 54. Try-Square with Fixed Blade

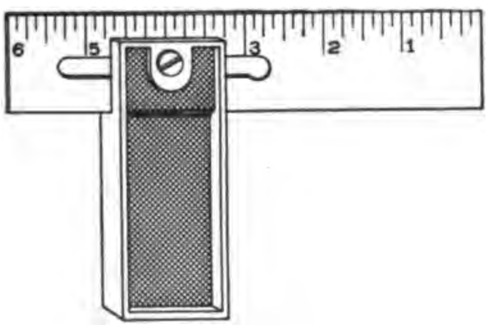


Fig. 55. Adjustable-Blade Try-Square

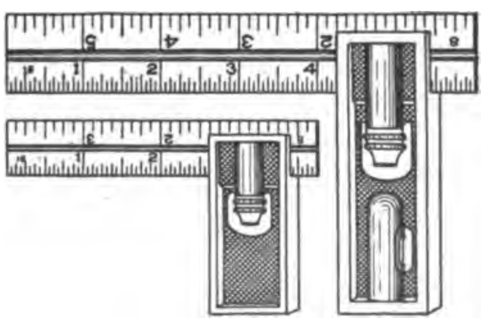


Fig. 56. Removable-Blade Try-Square

Adjustable Try-Square. The adjustable try-square, illustrated in Fig. 55, is not expensive, and will be found to fill the requirements of several small squares. It is made in two sizes, with graduated blades 4 inches and 6 inches in length, respectively. The blade of this square can be firmly secured in its seat at any point.. When the blade is carried entirely to the front of the handle, it is like an ordinary try-square; and the moving of the blade makes the square equally perfect down to $\frac{1}{4}$ inch length of blade, or even less. With one adjustable square of this kind, six inches in length, only one 8-inch or one 10-inch ordinary square will be necessary.

A still more convenient, but slightly more expensive, form of adjustable try-square is shown in Fig. 56. It differs from that

shown in Fig. 55, in being self-contained, no screwdriver being necessary for moving the blade or securing it in position, and also because the blade can be removed entirely, and an extra blade, shown in Fig. 57, substituted. The ends of this second blade give both the hexagon and octagon angles, which is a matter of great convenience to the pattern maker. Fig. 57 shows the hexagon end of the blade applied to a hexagon nut. By reversing the blade the octagon end will be in position for use.

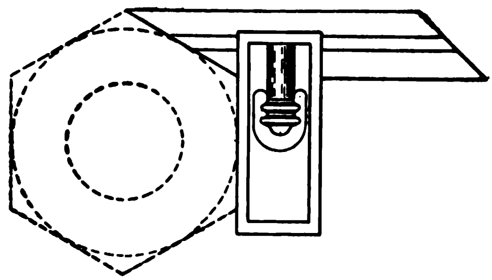


Fig. 57. Try-Square with Bevel-Ended Blade

Carpenter's Square. To the above try-squares there should be added a carpenter's steel square, 24 inches by 18 inches, for use in laying out and squaring up large stock and large patterns.

Bevels. The bevel illustrated in Fig. 58, with the clamping screw in the end of the handle, is the most accurate and the most easily adjusted style of this indispensable tool. The blades are made from 6 to 12 inches in length, and have a slot in at one end, which admits of that end being adjusted to meet the requirements of the work.

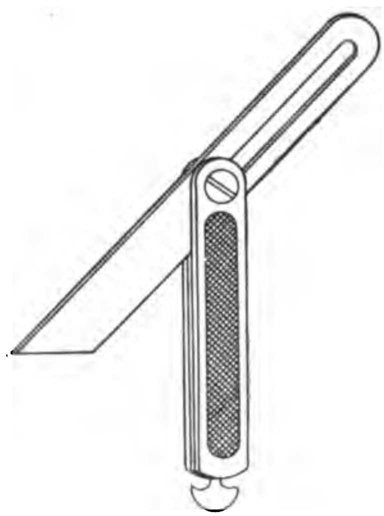


Fig. 58. Bevel

Universal Type. The small bevel illustrated in Fig. 59, like the adjustable try-square, is not an expensive tool, and will be found generally useful, especially in working the draft on patterns, and in turning the parts of patterns on the wood lathe which cannot be reached with an ordinary bevel. The offset in the blade increases its capacity and usefulness, so that any angle, however slight, may be obtained.

One 3-inch universal, and one 8-inch or 10-inch ordinary bevel, will meet all the requirements of the pattern maker for the beveled edges and surfaces and the draft of pattern work.

Rules. For all ordinary measurements, a 2-foot folding standard rule, Fig. 60, will be sufficient, but this rule must not be used

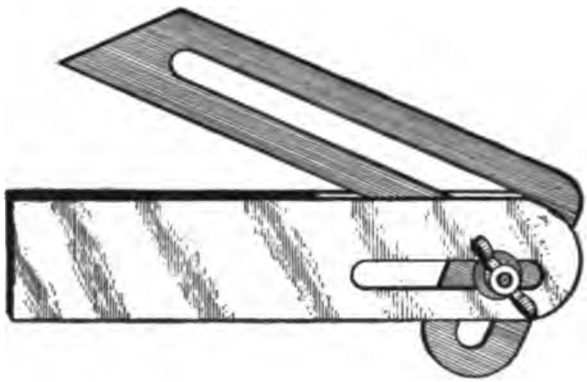


Fig. 59. Universal Bevel

for laying out or for working patterns, or any part of a pattern or core box, to the required dimensions.

Shrinkage Rule. For the molding dimensions of a pattern or core box a shrinkage rule must be used. The reasons are that when a mold made from the wooden pattern is filled with molten metal its temperature is very high, and as it cools and solidifies it con-

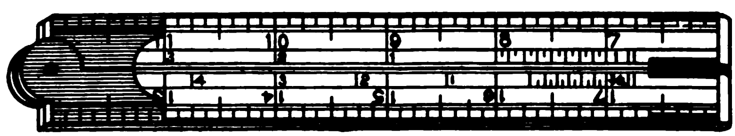


Fig. 60. Standard Folding Rule

tracts. Accordingly, to compensate for this, the pattern maker must add to the size of the pattern. In order that this may be done, and exact relations nevertheless be maintained for all dimensions, a shrinkage rule is used. This rule is marked off exactly like an ordinary rule, but if the two are compared, the shrinkage rule will be found to be about $\frac{1}{8}$ inch longer than the other for each foot of length.

The contraction or shrinkage of different metals in the molds varies greatly; that for cast iron being, as above stated, $\frac{1}{8}$ inch to each foot. For brass, however, the shrinkage is $\frac{3}{16}$ inch to the foot; and for many of the softer metals it is as great as $\frac{1}{4}$ inch per foot.

Shrinkage rules, Fig. 61, are usually made of a single piece of boxwood or beech; those for cast iron being $24\frac{1}{4}$ inches long, for

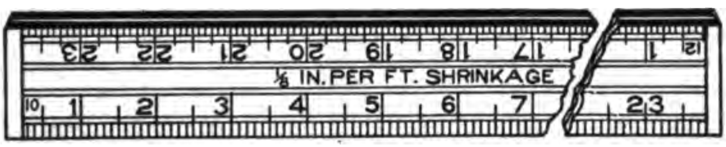


Fig. 61. Shrinkage Rule

brass $24\frac{3}{8}$ inches long, and for other soft metals $24\frac{1}{2}$ inches in length. They can also be bought made of tempered steel $12\frac{1}{8}$ inches, $12\frac{3}{16}$ inches, and $12\frac{1}{4}$ inches in length. In making use of the shrinkage rule, the workman will proceed just as though he were using a standard rule; and when the pattern is completed it will be found to be larger in all its dimensions, just in proportion as the extra length of the shrinkage rule makes it greater than the standard rule.

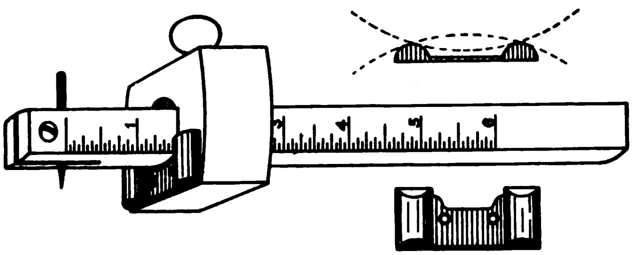


Fig. 62. Improved Marking Gage

Marking Tools. *Marking Gage.* The marking gage is used for drawing a line at a given distance from, and parallel to, the already trued and jointed surface or edge of a board or piece of wood that is being marked to dimensions.

There are many forms of this tool, but in the improved gage, illustrated in Fig. 62, the head is reversible. The flat side of the head is used for ordinary straight work, while the reverse side, hav-

ing the brass face with two projecting ribs, enables the operator to run a gage line with perfect steadiness and accuracy around curves of any radius, either convex or concave—a feature much to be desired in a pattern-maker's gage.

Dividers. The ordinary woodworker's dividers can be bought in many forms, the most common being the screw-adjusting wing dividers shown in Fig. 63. This form is reliable, and is easily adjusted to the required distance between points. Moreover, when

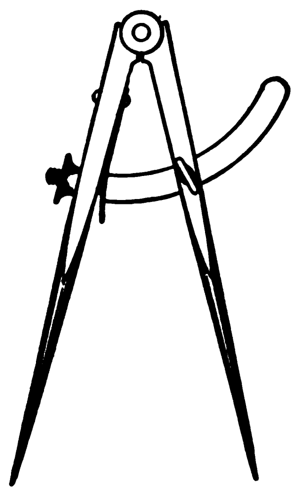


Fig. 63. Common Wing Dividers

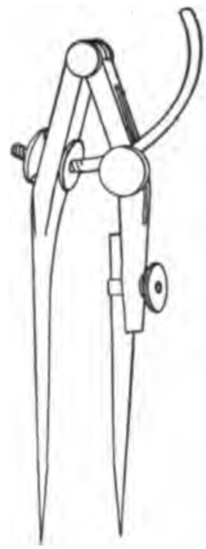


Fig. 64. Removable-Point Dividers

clamped by the thumbscrew, it is not liable to be altered by a slight blow in handling.

Another and improved form is shown in Fig. 64, one leg of which is removable so that a pencil can be inserted. This will be found very convenient for marking and laying out work.

For spacing the teeth of gear wheels, and for other work in which great accuracy is required, a pair of 2½-inch or 3-inch dividers, such as are shown in Fig. 65, will be found necessary.

Trammel. The trammel is used when the distance between the points to be reached is too great for the ordinary dividers. The trammel points are clamped to a beam of sufficient length to enable them to be set the required distance apart. They may be bought

plain, as in Fig. 66, or with one point adjustable, as in Fig. 67. The points are removable for the insertion of a pencil socket and pencil when needed.

For very accurate work, an excellent tool of this kind is illustrated in Fig. 68. The beams furnished are 4 inches and 13 inches in length. By the use of the cone center *V*, which may be substituted for the regular point center, the tool can be used for scribing a line around any hole already bored—sometimes a matter of great convenience. The complete set includes

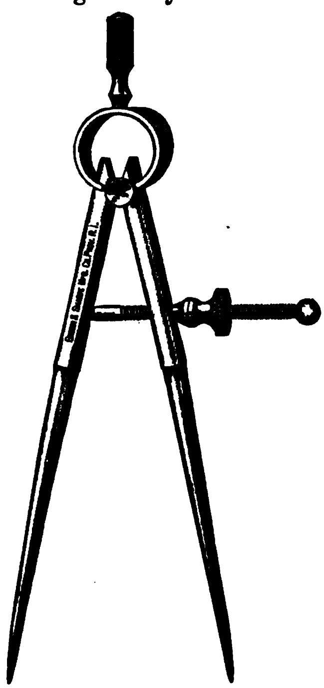


Fig. 65. Brown and Sharpe Spring-Joint Dividers

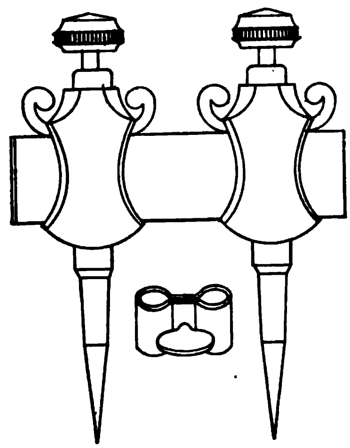


Fig. 66. Plain Trammel Points

the pen, pencil, straight and bent points, and the cone center, as shown in the cut.

Calipers. Calipers, like dividers, are made in many different forms with and without screw adjustment. Fig. 69 illustrates the screw-adjusting wing calipers for outside measurements, and Fig. 70 shows the firm-joint outside calipers used for the same purpose. Inside calipers for taking inside dimensions and inside distances are shown in Fig. 71, and the adjustable inside calipers are illustrated in Fig. 72.

Calipers are used for measuring the distances between points external and internal when a rule could not be used with accuracy.

They are indispensable to the wood turner for measuring the diameters of cylindrical forms and other work while being turned to

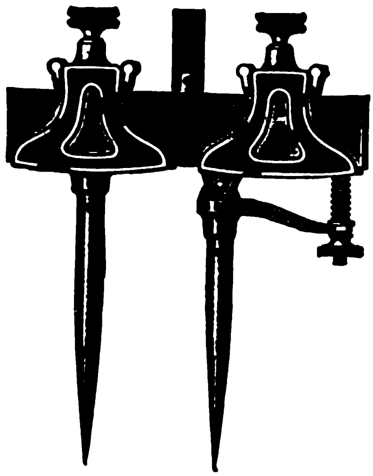


Fig. 67. Trammel with Adjustable Points

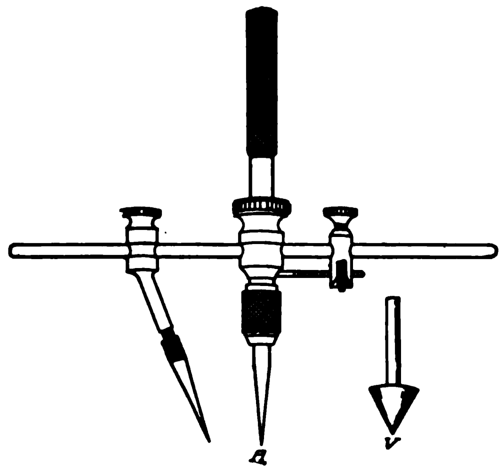


Fig. 68. Accurate Trammel Set

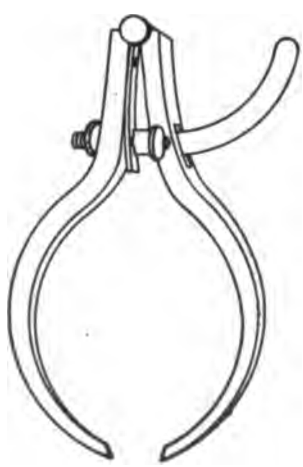


Fig. 69. Wing Calipers

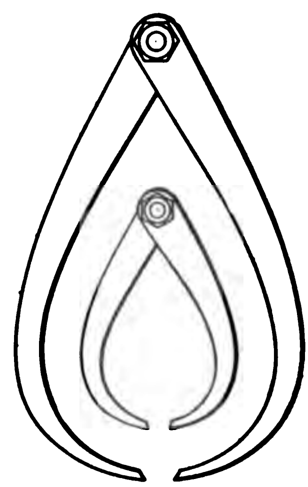


Fig. 70. Firm-Joint Calipers

required dimensions in the lathe. When used by the pattern maker, they may be applied while the wood is revolving, until it has been

reduced almost to the required dimensions; after which, when the calipers are used, the lathe should be stopped to prevent the surface from being marked by the points, and in order to obtain exact measurements. The calipers should not be pushed or forced over the piece, but in passing over the finished cylinder, the points should

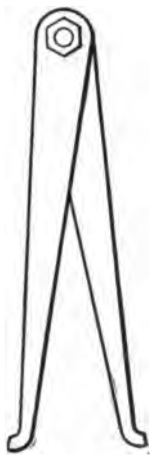


Fig. 71. Inside Calipers

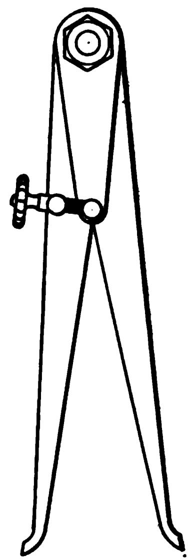


Fig. 72. Adjustable Inside Calipers

touch it lightly without springing the legs of the calipers; otherwise, the required dimensions cannot be obtained with accuracy.

MISCELLANEOUS SMALL TOOLS

Forcing Tools. *Hammer and Mallet.* There remain to be described a few tools, which, while necessary, are so common as hardly to require either illustration or description. Among these are the hammer, the best form of which for the pattern maker is shown in Fig. 73, and the mallet, of which the best form is shown in Fig. 74.

A mallet that is to be used on the handle of firmer chisels and other pattern-maker's tools, should not be made of hickory or of lignum-vitae, nor have hard-rubber or hard-fiber facing. Mallets

thus made soon mar, splinter, and destroy the tool handles on which they are used. Beechwood and maple furnish the best material for mallet heads for the use of the woodworker who works

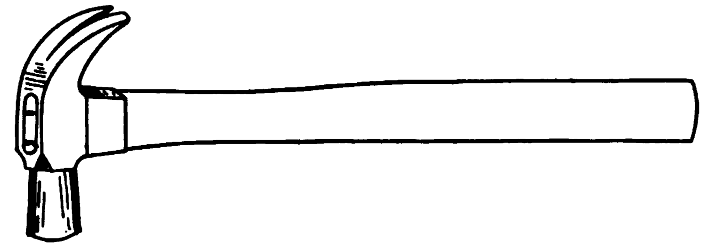


Fig. 73. Typical Pattern Maker's Hammer

in pine and other soft woods. It is true that the mallet head will not last so long if made of beech or maple wood, but the chisel and gouge handles will be protected, which is a matter of much greater importance.

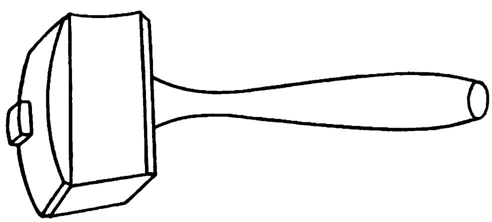


Fig. 74. Mallet

Screwdriver and Awls. Of the screwdriver, illustrated in Fig. 75, at least two or three sizes will be found necessary.

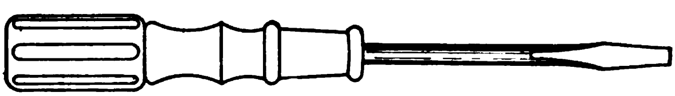


Fig. 75. Ordinary Screwdriver

The scratch awl, Fig. 76—although but little employed at the work bench, where a knife is used in its place for all accurate markings—is indispensable to the pattern maker for laying out the dimensions on his work while it is revolving in the turning lathe. It should be long and slender, as shown, and is used on the revolving wood by placing it over the required graduation of the rule, while the latter is held on the tool rest.

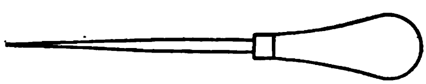


Fig. 76. Scratch Awl

Brads and small wire nails must often be driven at such an angle to the grain of the wood, or in such a position, as to make it necessary first to bore a small hole in order to start the brad in the required direction. The brad awl, illustrated in Fig. 77, is a convenient tool for this purpose. It is commonly ground to a chisel point, as shown at *a*, but will be less liable to cause splitting, and will work

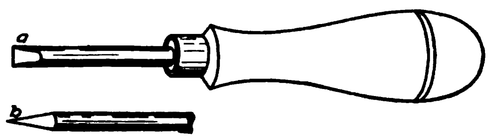


Fig. 77. Brad Awl

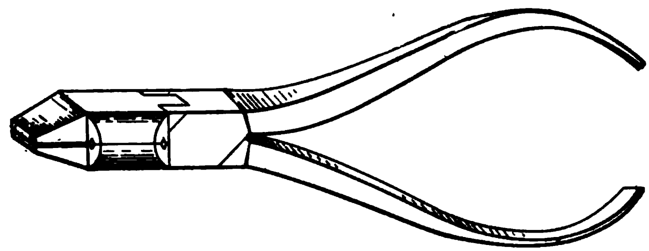


Fig. 78. Side-Cutting Pliers

faster and with greater ease, if ground to a double spear point, as shown at *b*. The four corners, if kept sharp, will enter the wood and cut faster than the chisel point.

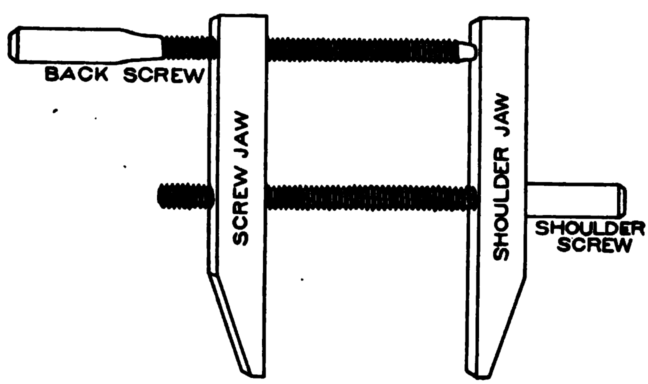


Fig. 79. Wooden Clamp

Pliers and Clamps. Side-cutting pliers, such as are illustrated in Fig. 78, will be found convenient not only for cutting off wire

and brads, but for removing small brads and for holding small pieces while being worked to shape.

Every pattern shop should have at least one dozen each of three or four different sizes of hand screws or clamps similar to that shown in Fig. 79. These are adjustable through wide ranges. They are used for clamping together the material that is being glued up to form the different parts of a pattern, and are convenient also for many other purposes. The all-iron C-clamp, shown in Fig. 80, is sometimes useful in positions that are hard to reach with a hand screw. The method of adjusting and of using the hand screw will be fully explained later.

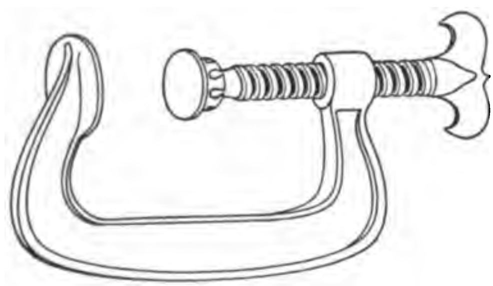


Fig. 80. Iron Clamp

Abrading Tools. *Wood Files.* The half-round cabinet file and half-round cabinet rasp, shown in Fig. 81, enter largely into the work of the pattern maker, and should be bought in sizes each of 6 inches, 8 inches, and 10 inches. Larger as well as intermediate sizes may often be found necessary, but will not be needed for ordinary work.

Oil Stones and Slips. As before stated, new planes, chisels, and other edged tools, if of the best quality, are always sold ground and sharpened, ready for use. When used, however, they soon become dulled, and must then be resharpened, and be so kept as to have a smooth keen cutting edge in order to do good work and to work rapidly. The method employed for doing this is the same for all edged tools, whether ground and sharpened on one side or on both sides.

Oil stones are used for plane irons, chisels, and all flat and straightedged tools; and oil slips, having rounded edges, are used for gouges, and for all tools having curved edges. They are made of different sizes, and may be found of many and widely different qualities. The best known and most widely used oil stones in this country, and perhaps in the world, are the Washita, of which the Lily White Washita brand, being carefully selected, is the most

even in grade and quality, and is the best-adapted natural stone for woodworkers' tools. For wood-turners' and pattern-makers' tools, the sharpening qualities of the Washita are unsurpassed; but the quality differs greatly in stones sold under this name, some being uneven in hardness, and some soft and worthless. No trouble will be found, however, if some well selected brand such as the one mentioned above is chosen.

The Arkansas oil stones are claimed to be the hardest and finest oil stones in the world. They are composed of nearly pure silica in the form of minute crystals interpenetrating one another, and differ from the Washita only in the minuteness of the crystals and in their more compact arrangement. They are consequently very much harder, and cut hardened steel more slowly than coarser grades of stone, but impart a finer and smoother edge to the tool. They are used by wood carvers, engravers, watchmakers, and others using tools that require a very fine edge or point. They are expensive, and should be used carefully with equal parts of sperm oil and glycerine.

A good size for an oil stone is 6 inches to 8 inches in length, and from $1\frac{5}{8}$ inches to 2 inches in width. The thickness does not matter, but the stones usually vary from $\frac{3}{4}$ inch to $1\frac{1}{4}$ inches in thickness. The oil slip should be about $4\frac{1}{2}$ inches in length, and from $1\frac{3}{4}$ inches to 2 inches in width, tapering from $\frac{5}{8}$ inch on one edge to $\frac{3}{16}$ inch on the other, both edges being rounded as shown in Fig. 82.

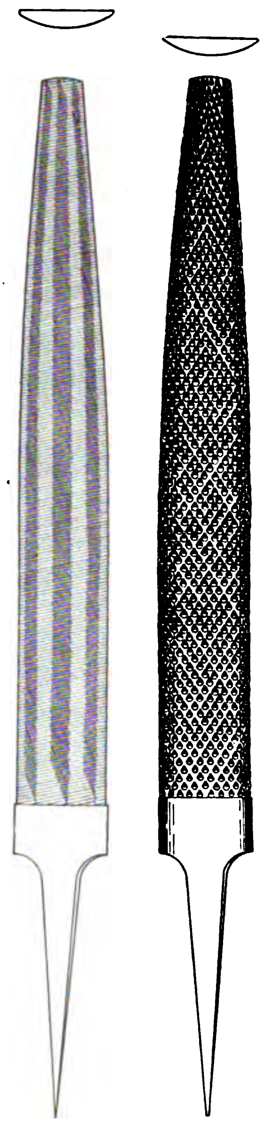


Fig. 81. Cabinet File and Rasp

In using the oil stone, care should be taken to hold the bevel of the tool flat, or nearly flat, on the stone, so that the cutting edge may

be kept thin and in easy working condition. The stone is held stationary on the work bench, and the tool is moved forward and backward over its face. In the use of the oil slip, on the other hand,

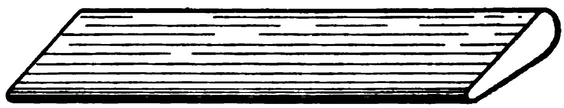


Fig. 82. Oil Slip

the tool is held stationary, with the cutting edge or end up, and the slip is rubbed over the beveled surface with a circular motion or stroke, until a keen sharp edge has again been imparted to it. An abundance of oil should always be used in order that a finer and smoother edge may be given to the tool, and the pores of the stone be kept clean and free from glazing.

In the last few years an entirely new variety of oil stone and oil slip has been placed on the market. It is called the India oil stone, and is made from corundum, the hardest of all mineral substances except the diamond. These stones have wonderful cutting qualities, and differ greatly from other oil stones in that they cut steel much faster, impart better edges, and do not glaze. They are also of uniform texture throughout. India oil stones are furnished in three grades—coarse, medium, and fine—and in all required shapes, a few of which are shown in Fig. 83. Only the fine stones are adapted for woodworking tools and for those classes of tools requiring a fine cutting edge.

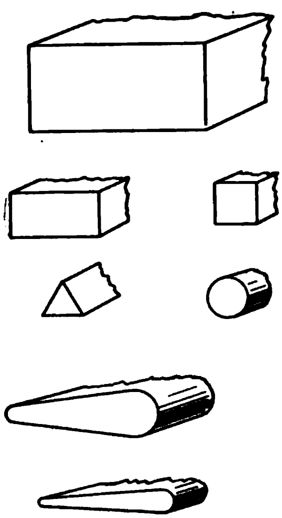


Fig. 83. Shapes of Oil Stones

Grindstones. Second in importance to a good oil stone is the grindstone, power driven if possible. It should not be too close-grained. A rapid cutting stone, even if moderately coarse, is greatly to be preferred, as all ground edges must be finally finished on the oil stone however finely they may have been ground on the grindstone. A stone about 36 inches in diameter when new,

is a good size, and can be bought with a suitable cast-iron trough underneath, and also with an arrangement for supplying the water necessary to keep the stone wet.

In all stones there will be found great differences of hardness in different parts. Stones soon lose their cylindrical shape and must be turned true. A piece of gas pipe or an old file will be found excellent tools for this purpose, but they must be used without water.

In using the grindstone for plane irons, chisels, and other tools that must be ground with a long bevel or to a thin edge, it is better to stand so that the stone runs toward the cutting edge of the tool, as shown in Fig. 84. This position grinds the tool much faster, and less of a feather will be turned up on the final edge. Scraping tools, however, and indeed all tools having a very short bevel, or whose edges are ground to a very obtuse angle, may be held so that the stone will revolve away from the cutting edge of the tool, this position being less liable to cut hollows in the face of the stone. This method of grinding, however, is too slow for tools having a long bevel, and which for that reason require more grinding.

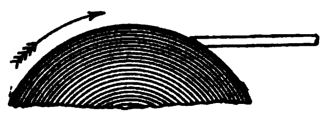


Fig. 84. Grinding Long Bevel

When to use the grindstone is a question that often occurs to the beginner, who sometimes confuses the use of the grindstone with that of the oil stone. The grindstone is not in any sense an instrument for sharpening woodworkers' tools. When a chisel or a plane iron has been sharpened on the oil stone for several successive times, the bevel is gradually worn shorter, and its shape changed from that shown at *a*, Fig. 85, to a shape similar to that shown at *b*. When the length of the bevel is thus reduced, the angle of the cutting edge is too obtuse to do good work or to work easily. The metal at *c* must then be ground off on the grindstone, and the bevel of the tool restored to its former correct shape, as shown at *a*, after which the cutting edge must be sharpened and finished on the oil stone.

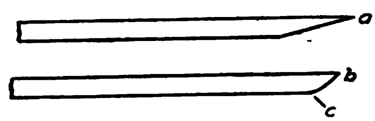


Fig. 85. Sharp and Worn Bevels

MACHINE TOOLS

Turning Equipment. Of all power-driven machines, the most indispensable to the pattern maker is the wood-turning lathe. In a small shop where small patterns only are made, a 14-inch or a 16-inch speed lathe, such as is shown in Fig. 86, may prove sufficient for all purposes; but if only one lathe can be afforded, it should be a regular pattern-maker's lathe, similar to that illustrated in Fig. 87.

Pattern-Maker's Lathe. The pattern-maker's lathe differs from the speed lathe in that the headstock spindle extends through the

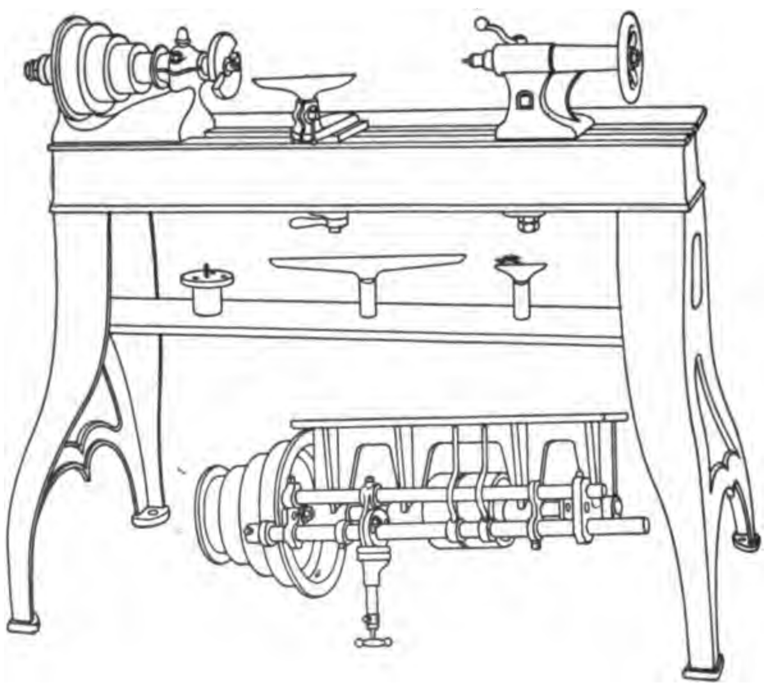


Fig. 86. Speed Lathe

left-hand bearing, and is fitted to receive faceplates and chucks the same as on the inside end. The arrangement of the countershaft is also such as to give a much wider range of speed to the lathe head, so that pieces of very large diameter may be turned at a speed proportioned to their sizes. These lathes are also fitted with a hand-feed slide rest—either compound, as shown in the illustration, or a plain sliding tool holder moved by a rack and pinion, as may be

desired. The tailstock is arranged with a cross adjustment to facilitate turning long cylinders tapering if required. When not in use the slide rest may be removed from the lathe, and the ordinary tool rest and rest socket substituted in its place for hand-turning. The speed at which a lathe should be run is always indicated by the manufacturer, the countershaft usually running at a speed of 500 to 550 revolutions per minute.

Chucks and Faceplates. A variety of chucks and faceplates for holding the work are always furnished with a lathe. Some of these are shown in the engraving, the screw chuck being shown at *a*,

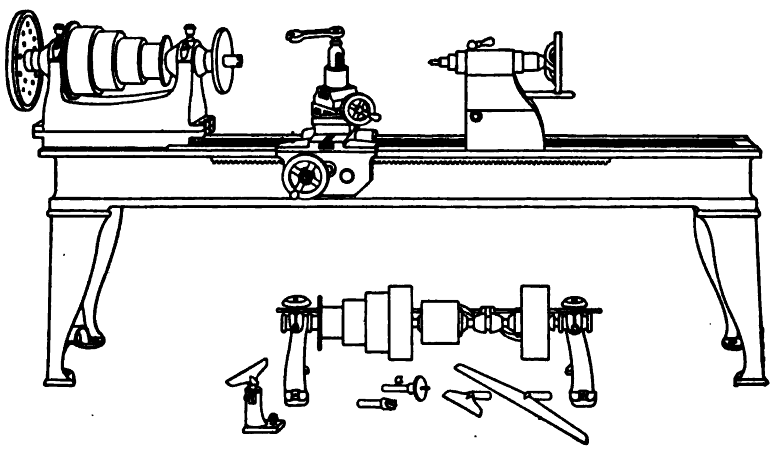


Fig. 87. Pattern Maker's Lathe

Fig. 87, and two of the iron faceplates are shown, one on each end of the spindle.

In addition to these faceplates, which really form the base only for chucking the pattern, wooden chucks must be used between the iron faceplate and the pattern. These wooden faceplates are constructed in a variety of ways by different pattern makers; but for small patterns it is necessary to use only a plain board $\frac{7}{8}$ inch to $1\frac{1}{4}$ inches thick, of a slightly greater diameter than the required pattern, and screwed fast to the iron faceplate, as shown in Fig. 88. To this, after being placed in the lathe and turned true, the pattern is attached, as will be fully illustrated and described farther on. For patterns of a medium size, say 20 inches to 30 inches in diameter,

the board should be stiffened by means of a wide wooden bar firmly screwed across the back, as in Fig. 89.

When needed for very large or heavy work, the chuck, in order to prevent vibration, must be strong in proportion. It is best made as illustrated in Fig. 90, in which the front of the chuck, as shown at *a*, will be least affected by the moisture in the air if left unglued, or at best only tongued and grooved, being held together by the crossbars only, as shown at *b*, to which it is firmly screwed, without glue. This chuck is simple and cheap, and will be found in practice much stronger and more rigid than one built up of sectors or in a more elaborate way.

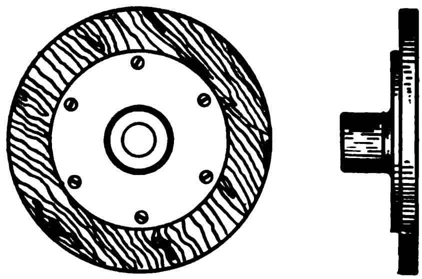


Fig. 88. Construction of Small Faceplate

Turning Gouge. Of lathe hand tools the first to be considered, as also the first to be used, is the gouge. It is used for reducing the stock to be turned, from a rough or rectangular shape to a cylindrical form, preparatory to smoothing and finishing. It is ground and beveled on the back or convex side, and the shape of the cutting edge should be of the same curvature as the inside, or upper side, of the tool. Gouges are made in all sizes, one of which is illustrated in Fig. 91; but for the pattern maker's use four gouges, ranging from $\frac{1}{4}$ inch to $1\frac{1}{4}$ inches, will be found sufficient for all purposes.

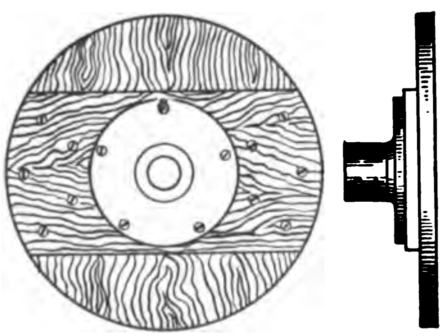
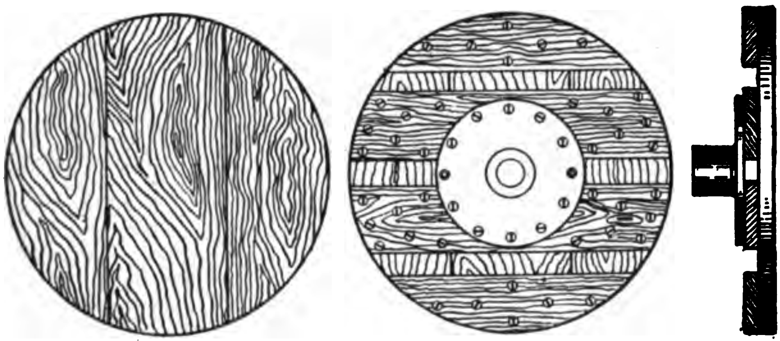


Fig. 89. Medium-Sized Faceplate Construction

Before using the gouge, and indeed any lathe cutting tool, the workman should take care to see that the tool rest has been elevated above the center line of the lathe centers, from $\frac{1}{4}$ inch for small work, to 1 inch or more for large work. The position of the gouge, when in use, is horizontal and at about a right angle to the tool rest. It should not, however, be laid on

the rest so as to use only the extreme point of the tool, but should be tilted over, first to one side and then to the other, so as to bring all



a b

Fig. 90. Strongly Braced Faceplate for Large Work

parts of the cutting edge, successively, in contact with the wood that is being turned.

The gouge may be used by the beginner without hesitation, as in no position, whether tilted or on its back, will it catch or rip into the wood. The tool should be held firmly by the extreme end of the handle, in the right hand, while the left hand rests against

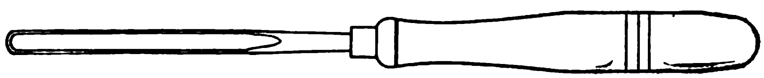


Fig. 91. Turning Gouge

the tool rest, the blade of the tool being grasped lightly with the fingers, and passing through and under the left hand while resting on the tool rest.

Skew Chisel. As the turning gouge—being curved—can be used only as a roughing-down tool or for turning out hollows, and cannot

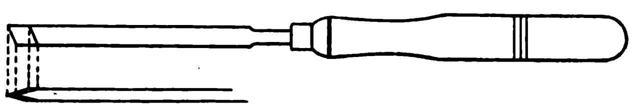


Fig. 92. Skew Chisel

be used for finishing, the skew chisel, one size of which is shown in Fig. 92, is used, in common and ornamental turning to make a

straight, true, or smooth surface. This form of chisel is made in all sizes from ⅛ inch to 2½ inches in width, but, unlike the gouge, requires considerable practice and skill for its successful use.

The skew chisel is held slightly tilted in order that while the short edge of the blade touches the tool rest, the long edge will be slightly above the rest, so that the long corner of the skew point extends up and well over the cylinder which is being smoothed, thus preventing the long skew point from catching and tearing into the work. All the cutting must be done with the short part of the skew edge, say ½ inch only of the cutting edge, the tool resting not only on the tool rest, but resting also firmly on the cylinder that is being turned, just as a plane rests on a board while cutting and removing the shavings from its surface. The right position for this tool is hard to obtain at first, and can be acquired only by patient and continued practice. In no case, however, should the skew chisel be held flat on the tool rest, or used as a scraper, this not being allowable or good practice either in common or in ornamental turning. One skew chisel each of the ¼-inch, ½-inch, 1-inch, and 1½-inch sizes will be found sufficient for all ordinary work.

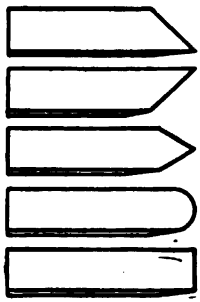


Fig. 93. Scraping Tools

Scraping Tools. While the skew chisel works with great rapidity and does smooth and very satisfactory work in all kinds of ornamental turning, the dimensions obtained with this tool are not so accurate for pattern work as those obtained by the regular pattern maker's scraping tools. These tools, whatever may be the shape of the points or cutting edges, are all flat like the skew chisel, and are ground or beveled on one side only. Indeed there is no better wide scraping tool for large surfaces than a common firmer chisel after it has been worn short so as to be free from vibration.

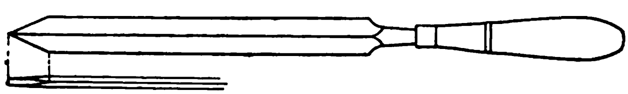


Fig. 94. Cutting-Off Tool

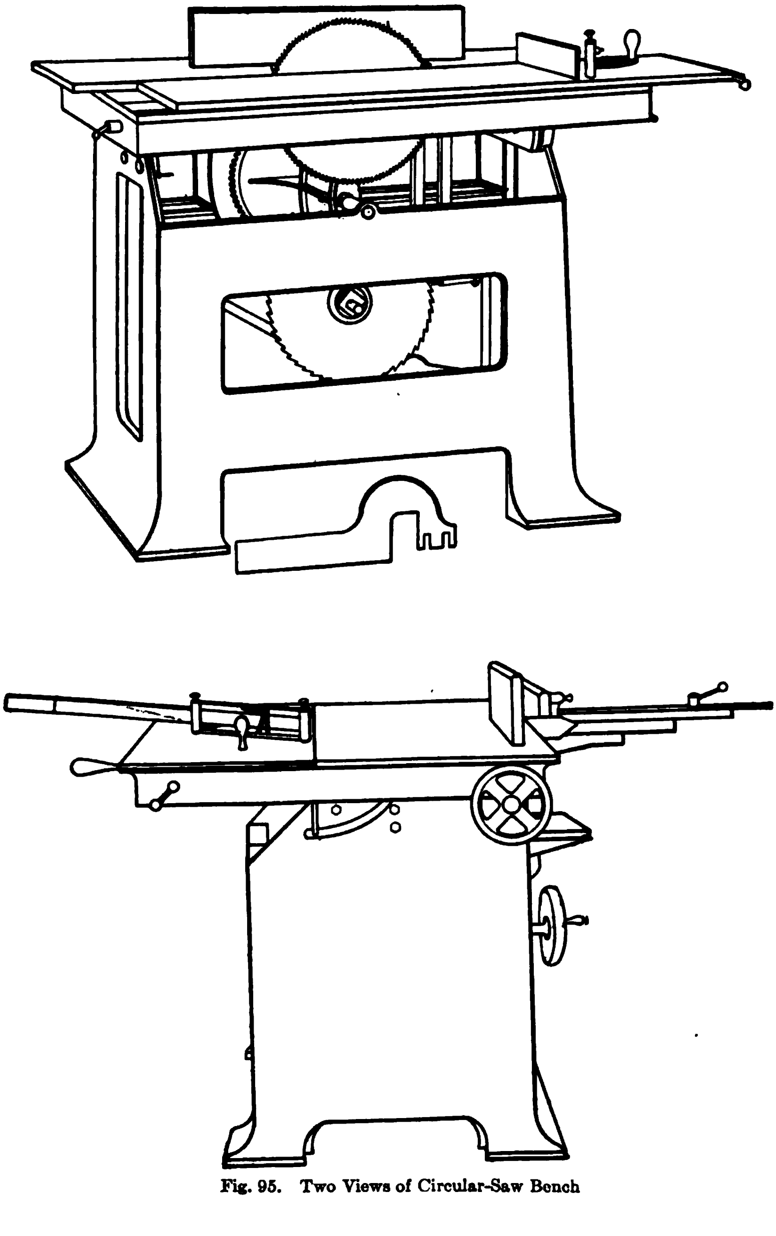


Fig. 95. Two Views of Circular-Saw Bench

Scraping tools are made in many forms and shapes, and are ground by the workman to suit the requirements of his work. A few of the many shapes in common use are illustrated in Fig. 93.

These tools should be ground with a very short bevel, and must be sharpened much oftener than a cutting tool. The revolving wood, passing at right angles to the sharp edge, wears it away more quickly than it can a cutting tool, for the latter is also worn away on the slanting side of the bevel.

Cutting-Off Tool. A very necessary tool for all kinds of wood turning is the parting or cutting-off tool, shown in Fig. 94. This is used as a scraping tool for cutting recesses in the work and for cutting off finished work from the faceplate, and will also be found useful for many other purposes.

Sawing Machines. *Circular Saw.* As a time-saving and labor-saving machine a good circular-saw bench is necessary in every well-equipped pattern shop, and is unsurpassed in capacity and in the variety of work for which it may be used. As shown in one of the views in Fig. 95, it is permanently provided with two saw arbors one carrying a rip saw and the other a crosscut saw, either of which may be raised easily and quickly to cutting position, the other being depressed at the same time. The front half of the table is made to slide, while the whole table can be tilted to an angle of 45 degrees, and will remain in any position desired without clamping. As shown, it is provided with adjustable gages for cross-cutting or mitering, and with an adjustable fence for ripping, all of which are removable at will, leaving the whole upper surface of the table clear. Fig. 96 gives a view of the table from above. As in the case of the turning lathe, the intended speed of the saw countershaft is indicated by the manufacturer.

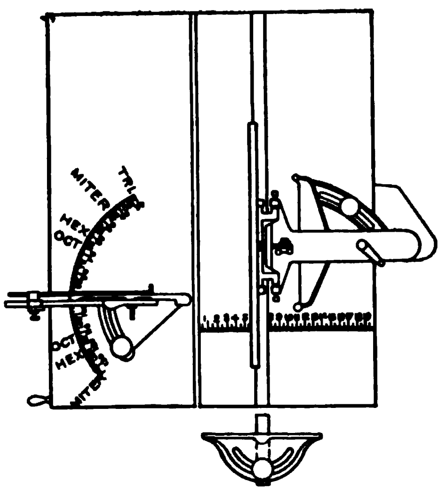


Fig. 96. Plan of Saw Table

The single-arbor circular-saw bench, shown in Fig. 97, is a less expensive machine than that just described; but the time lost in having continually to change the saw on the single arbor from rip to crosscut and back again for pattern work is a very annoying as well as expensive inconvenience.

Band Saw. A good band saw, such as the one illustrated in Fig. 98, is indispensable for cutting the curves and irregular shapes that form a part of so many patterns. The best machines of this

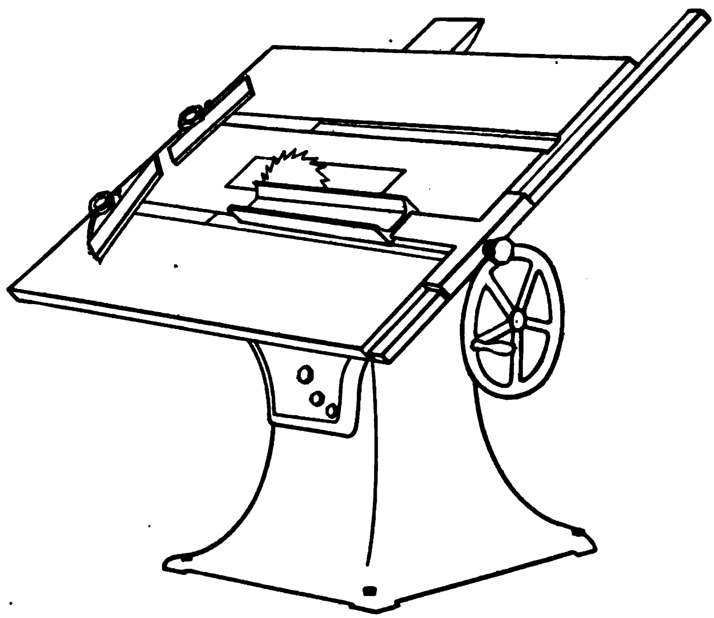


Fig. 97. Single-Arbor Saw Bench

description have a tilting table which can be set and clamped at any angle, enabling the workman to give the required bevel or draft to his work.

With a sharp and well-kept saw, there is no more rapid or correct method of cutting out and making circular core boxes of all sizes whose length is within the capacity of the machine. The block from which the core box is to be made must be cut perfectly square on the end which is to rest on the saw table, and, if this end of the block is not large enough to give sufficient base to hold it in an upright position, the block can be supported against the blade of

a try-square, or, better still, against a wooden bracket made for the purpose.

Scroll Saw. The scroll saw, illustrated in Fig. 99, is necessary for cutting inside curves and openings in which a band saw could not be used. Like the band saw, it should have a tilting table. Where both saws cannot be afforded, the scroll saw takes the place of both. While not working so rapidly as the continuously cutting blade of the band saw, it is, when kept sharp and in good running condition, a great time- and labor-saving machine.

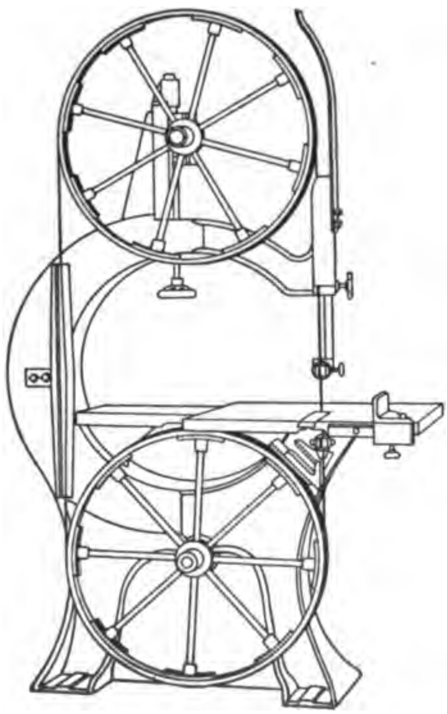


Fig. 98. Band Saw

Planers. Because of the fact that pattern lumber can be bought already dressed to any required thickness, a planing machine is not found in every pattern shop. The ordinary surface planer, however, will not take out the twist, or wind (ī as in find), and the curves from the surface of the lumber—a matter of very great importance in pattern work, and one which requires a great deal of time if the planing is done by hand.

Hand Planer and Jointer. The hand planer and jointer, illustrated in Fig. 100, is almost indispensable, not only for facing the sides of the boards perfectly true, straight, and free from wind, but also for jointing the edges, and for making perfectly fitting glue joints in a manner superior to any hand work. These machines can be bought in widths of from 12 to 30 inches. A machine 16 inches wide is a very desirable size for pattern work.

It will readily be seen that the running of a board over the hand planer, while facing the surface straight and true, will not reduce

the piece to a uniform thickness. To avoid the necessity for much hand work in accomplishing this result, first face the piece on the hand planer so as to make one true side, and then run it through a surface planer similar to the one illustrated in Fig. 101. If they can be afforded, both of these machines, especially the hand planer, will return large profits on the money invested in them, because of the time and labor saved and the superior quality of the work done.

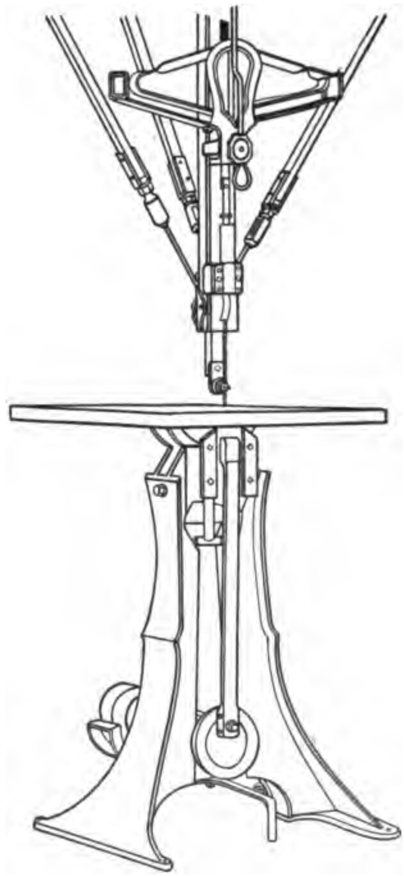


Fig. 99. Scroll Saw

Trimmers. Among the many labor-saving tools of late years, there is perhaps none more popular and none more indispensable in a pattern shop than the universal wood trimmer. It will cut any end or angle within the capacity of the machine; and an end which would take from 10 to 15 minutes to square and true up correctly by hand, with square and plane or chisel, can be finished in as many seconds with this tool. It is made in many sizes, from the small bench trimmer, two views of which are shown in Fig. 102, to the large machine illustrated in Fig. 103. The small No. 0 machine, shown in Fig. 102, cutting to 6 inches wide and 3 inches high, is so comparatively inexpensive—considering the time it will save and the quality of the work produced—that it should be on the bench of every pattern maker. The larger machine will cut $20\frac{1}{2}$ inches wide and to a height of $7\frac{1}{2}$ inches. These machines will cut the acute angles between 45 degrees and 90 degrees, and the obtuse angles between 90 degrees and 135 degrees.

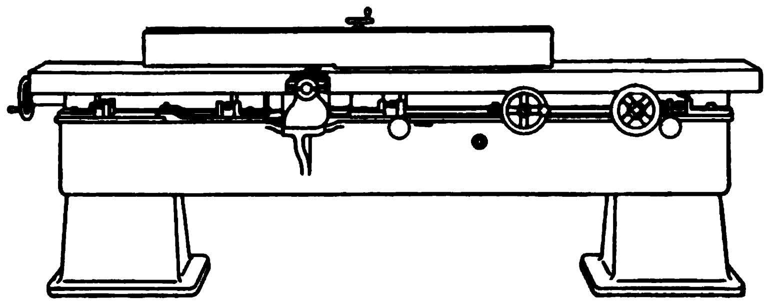


Fig. 100. Hand Planer and Jointer

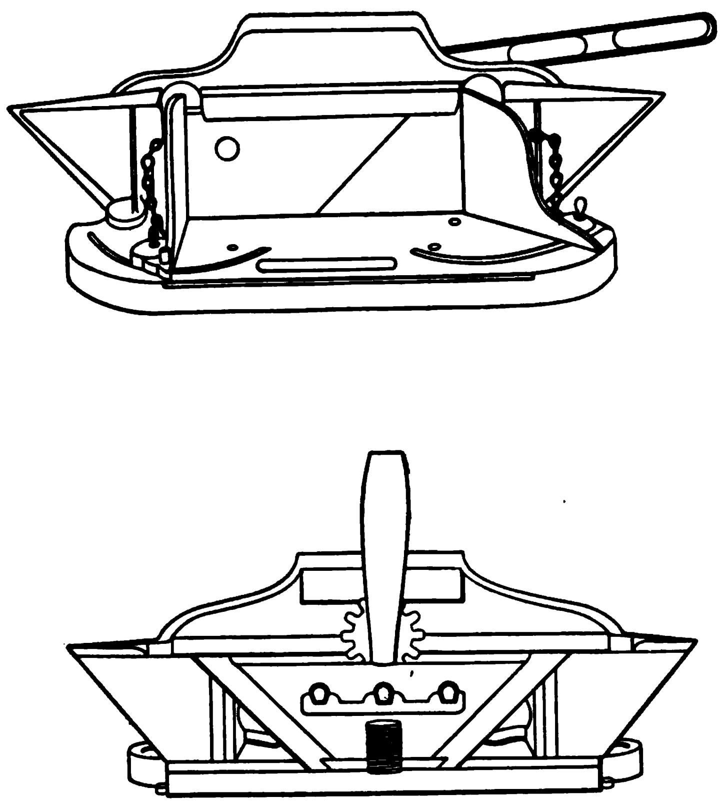


Fig. 102. Front and Rear Views of Bench Trimmer

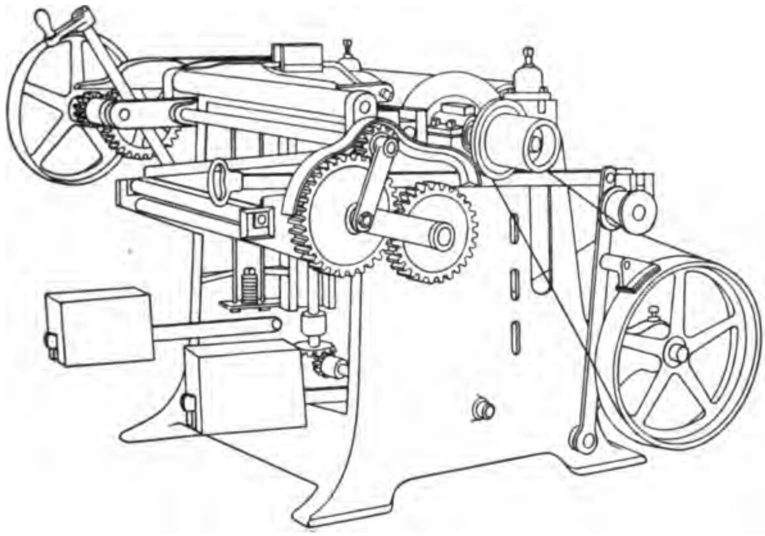


Fig. 101. Surface Planer

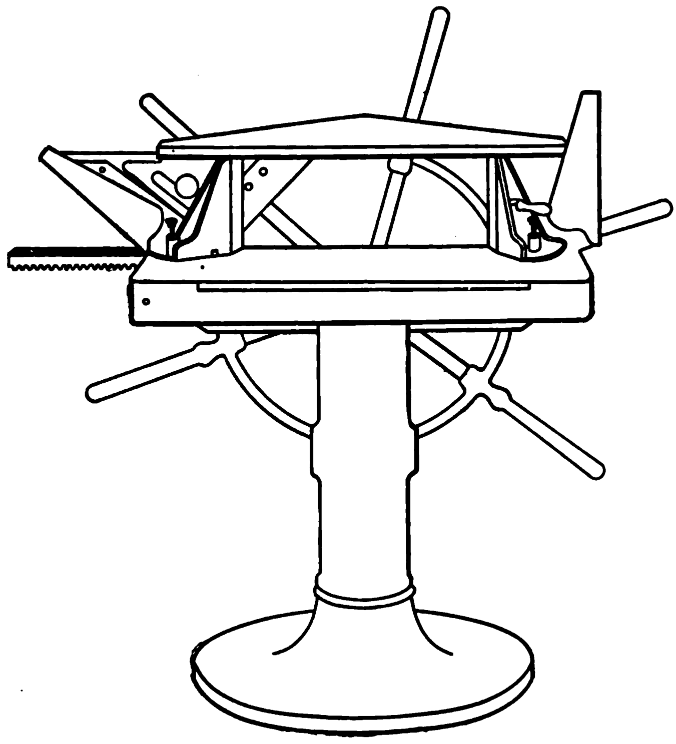


Fig. 103. Universal Trimmer

ALLOWANCES IN CONSTRUCTION

MOLDING PRACTICE

General Molding. As has already been said, it is necessary that the pattern maker should have some knowledge of molding in order that he may construct his patterns so that they can easily be removed from the sand. A brief description of the general method employed will suffice.

Use of Flask. Ordinarily, a casting is made in a flask, consisting of two parts, each containing its complement of sand—the upper part called the cope, and the lower part the nowel or drag. The pattern is sometimes made in two pieces that separate or part along the line separating the cope and the drag. Thus, in Fig. 104 the pattern separates with the flask on the line *A B*, and, when so separated, the cope is turned upside down, and the portion *C* of the pattern is lifted out. The portion *D* is lifted out of the drag in the same way.

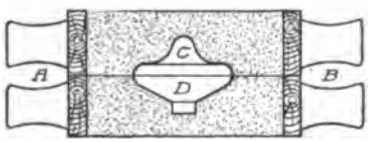


Fig. 104. Flask Showing Parting

Cores for Hollow Castings. In the case of molding a hollow object, the internal cavity in the casting is formed by means of a dry-sand core which rests in impressions made in the sand by core prints attached to, and forming a part of, the pattern.

To illustrate this, let it be required to cast the hollow cylinder shown in Fig. 105. The wooden pattern necessary to produce this

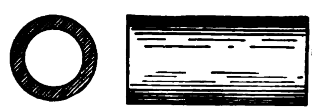


Fig. 105. Hollow Cylinder

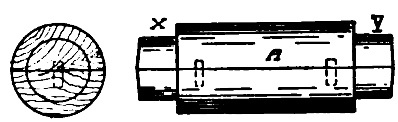


Fig. 106. Cylinder Split Pattern with Core Prints

hollow cylinder is shown in Fig. 106, which, as will be seen, represents the cylinder only externally by the part *A*. The core prints, one on each end of *A*, are represented by *x* and *y*. These projections form part of the pattern, and make their impressions in the sand with the part *A*, which alone represents the required cylinder. For making the core, the length of the inside of the core box, in

which the dry-sand core is formed, will be the extreme length of the pattern including x and y, and the inside width will be the exact diameter of the core prints. In this case, the core being a cylinder, only a half-core box, Fig. 107, is used. In it are made two semi-cylindrical cores, which, after being dried, are cemented together, thus forming the complete cylindrical core required.

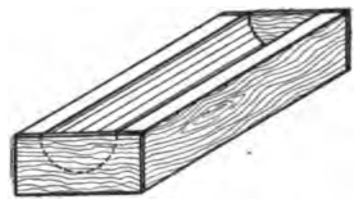


Fig. 107. Half-Core Box

Molding Split Pattern. To mold this halved or split pattern, as it is called, the upper half of the pattern is laid on the molding board, and the drag is turned over it with the bottom side of the drag up and the parting side on the molding board, as shown in Fig. 108. After being rammed up, the drag and molding board are turned over and the board removed, when the parting of the pattern is exposed, the half-pattern being imbedded in the sand.

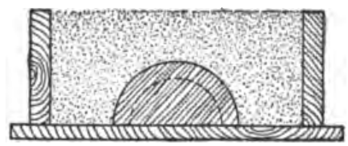


Fig. 108. Starting Split-Pattern Mold

The second half of the pattern is now placed in position on the first, and dry parting sand is spread over the surface of the wet or green sand; the cope is put in position on the drag, as shown in Fig. 109, and rammed up. Upon the cope and the drag being separated, the sand separates on the line to which the parting sand has been applied, which, as may be seen, is the line of parting of the cope and the drag, one-half of the pattern remaining in each.

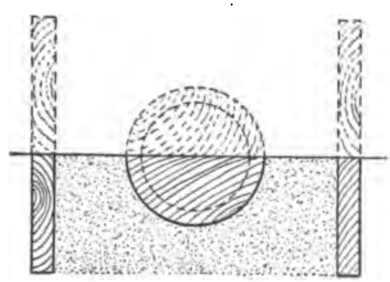


Fig. 109. Position for Molding Cope

After the halves of the pattern have been removed from the cope and from the drag, respectively, the completed dry-sand core is placed in the molds made by the core prints x and y. This core B is shown in position in Fig. 110, and entirely fills the parts of the mold made by x and y, leaving between itself and the surface of the mold made

by A room for the metal to be poured which is to form the required cylinder.

Coping Out for Solid Patterns. *Simple Cylinder.* In molding the above cylinder it is not necessary that the pattern should be

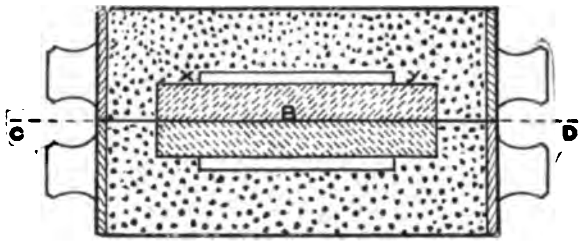


Fig. 110. Completed Mold with Core in Place

parted—made in two halves—as shown in Fig. 106. Patterns for small work, and even for large castings, are often made in one piece, as shown in Fig. 111. To mold this solid pattern it is placed on the

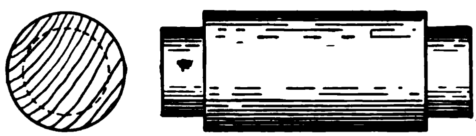


Fig. 111. Solid Pattern for Cylinder

molding board with sufficient sand to keep it from rolling, and the drag is inverted over it as before. When the drag has been rammed up, it is turned over, and will then present the appearance shown

Fig. 112. Solid Pattern Rammed in Drag

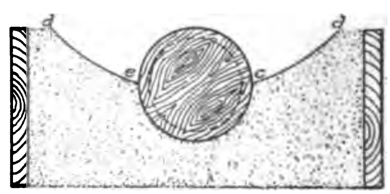


Fig. 113. Coped-Out Mold for Solid Patterns

in Fig. 112, the entire pattern being embedded in the sand. The sand is now cut away and removed, as shown in Fig. 113, down to the center line of the pattern. The cut sand is smoothed; and, after dry parting sand has been applied to the surface of the wet

sand, the cope is placed in position and rammed up as usual. Upon the cope being removed, the sand will part along the lines *de* and *cd*, leaving one-half of the entire pattern exposed. The pattern can now be lifted out, the core placed in position, and the cope returned to its place on the drag, when it is ready for the pouring, as in Fig. 110.

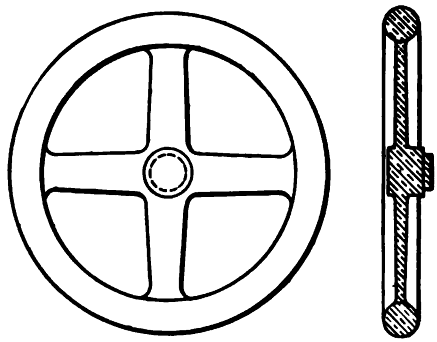


Fig. 114. Hand Wheel

Spoked Wheel. Another example of a one-piece pattern is the small brass hand wheel shown in Fig. 114. The pattern for this wheel is placed on the molding board, and the drag inverted over it and rammed up. After the drag has been turned

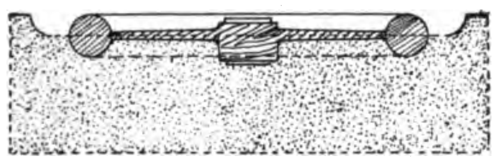


Fig. 115. Wheel Mold Coped Out

over, the sand is cut away and removed, not only down to the center of the rim, but also to the center line of the four arms, as shown by the dotted lines in Fig. 115. All cut surfaces of the sand are smoothed, parting sand is sprinkled over the parting thus made, and the cope is placed in position and rammed up. When the cope is lifted off, the sand will part half way down on the arms and rim, allowing the pattern to be taken out easily.

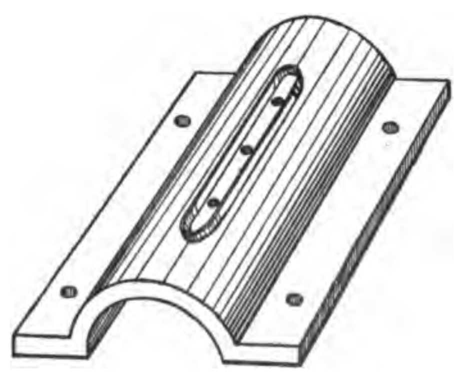


Fig. 116. Journal-Box Cap

Perforated Journal Cap. Still another example in

which a single-piece pattern can be used, is shown in the journal-box cap illustrated in Fig. 116. A cross-section of the pattern through two of the bolt-hole core prints is shown in Fig. 117. The pattern is placed on the molding board in the inverted drag, and is rammed

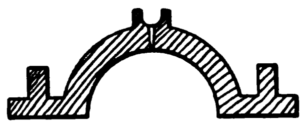


Fig. 117. Cross-Section of Cap Pattern

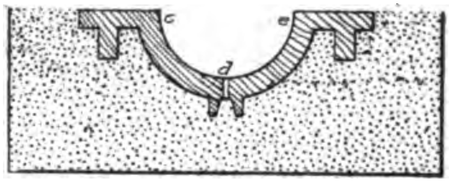


Fig. 118. Cap Rammed in Drag

up as usual. When the drag is turned over, the position of the pattern in the sand is as shown in cross-section in Fig. 118. The sand that may have entered the curve *cde* is lifted out, and the necessary draft is given to the sand at the two ends of the opening *cde*, as shown at *a*, Fig. 119. The cope is next placed in position, and when this has been rammed up and lifted off, the sand lying in

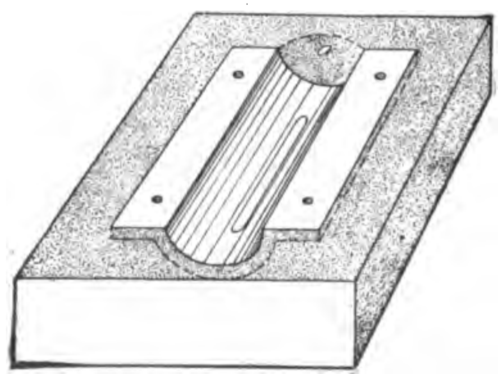


Fig. 119. Coped-Out Mold for Cap

the curve *cde* will be lifted with it. The pattern is now removed, the bolt-hole cores are placed in position, and the cope is returned to its place on the drag.

In this case the core prints should be in length at least twice the thickness of the metal through which the hole is to be cast, and the length of the cores will be equal to the thickness of the metal plus the length of the prints.

Molding Difficult Patterns. *Use of Green-Sand Ring.* In the small sheave pulley, Fig. 120, we have an example of a casting the construction of the pattern for which, so as to make it easily

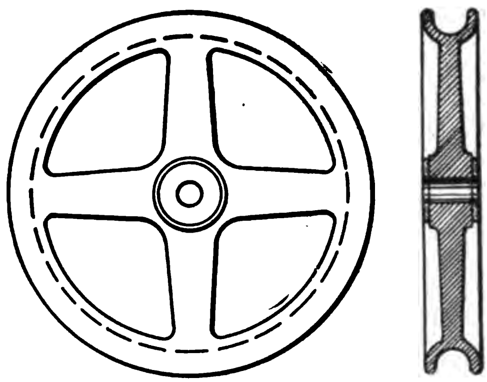


Fig. 120. Sheave Pulley

removable from the sand, may give some trouble to the beginner. The pattern is shown in cross-section in Fig. 121, and is molded in a two-part flask. At first it would seem impossible to place the pattern in the sand so that either half could be removed when the cope and drag are separated on the parting line of the pattern. This is readily accomplished, however, as follows:

Fig. 121. Pulley Split Pattern

The half pattern *C* is placed in the inverted drag, with the parting downward on the molding board, and is rammed up in the

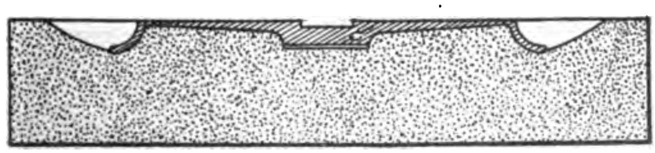


Fig. 122. Pulley Mold Coped-Out for Ring

usual way. After the drag is turned over, the sand is cut away and removed to the center of the rim edge, as shown in Fig. 122. The cut is carefully smoothed, and parting sand applied to the

cut surface. The part a of the pattern is placed in position on c, and is rammed up carefully, the sand being then cut away to the

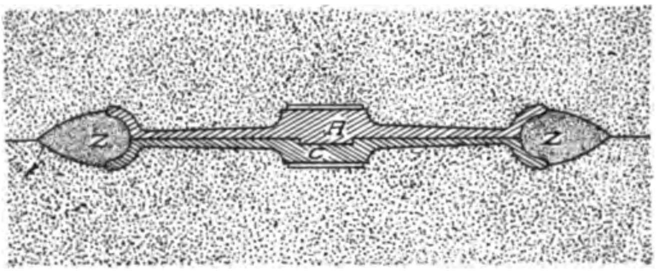


Fig. 123. Green-Sand Ring in Split-Pattern Mold

center of the rim edge of A. Parting sand is applied to the new surface, after which the cope is placed in position and rammed up.

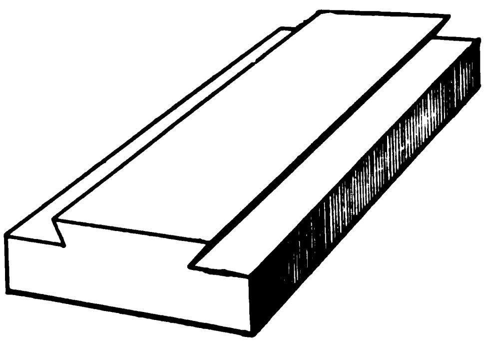


Fig. 124. Dovetailed Slide

When the cope and drag have been separated, the upper half A of the pattern is taken out, and the cope is returned to its place on the drag. The whole flask is now turned over, and the drag lifted off the cope, when the ring of green sand Z, Fig. 123, will rest on the cope sand and the part C of the pattern is taken out. We thus have two partings of the sand mold, but only one parting of the flask.

Fig. 125. Loose-Piece Pattern

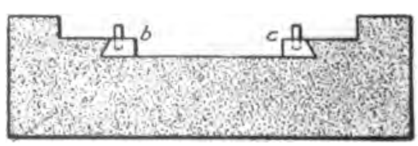


Fig. 126. Loose Pieces in Mold

Many other examples might be given, as the case of the common two-flange pulley, which, when small, is often molded in this way.

Loose-Piece Patterns. It is frequently the case that parts of the pattern will overhang so that the pattern cannot be removed from the sand in any direction, even if parted. In such cases the

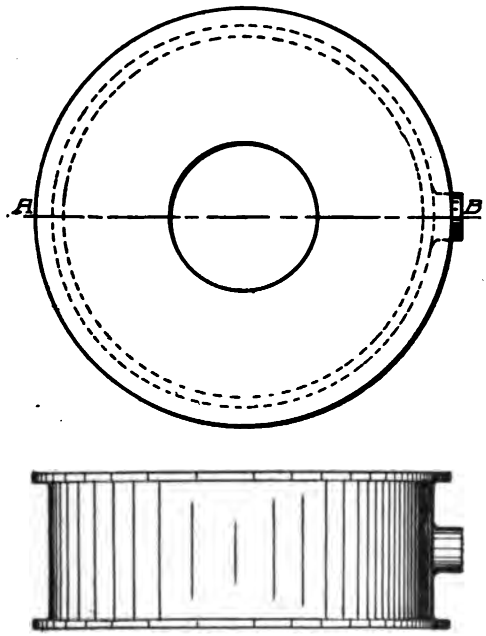


Fig. 127. Turbine Case

overhanging parts are fastened loosely to the main part of the pattern by wires or wooden pins. An example of such a casting is shown in the slide, Fig. 124. A cross-section of the pattern for this slide is shown in Fig. 125, in which the two overhanging parts are held in position by the use of pins. After being rammed up, the part *A* is removed, leaving the parts *b* and *c* still in their positions in the sand, as shown in Fig. 126. These may now be carefully removed toward the center of the opening and lifted out.

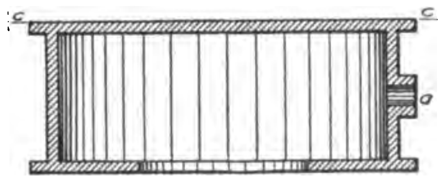


Fig. 128. Section of Casting, Fig. 127

Use of Dry-Sand Cores. In some cases there is not sufficient room, when the main part of the pattern has been taken from the

mold, to remove the projecting pieces. In such cases, the overhanging pieces or projections must be made by using dry-sand cores. To illustrate this, we shall consider the pattern for the small cast-iron turbine case illustrated in Fig. 127.

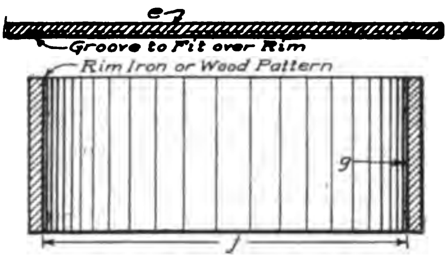


Fig. 129. Section of Rim and Top, Fig. 127

A section view of the casting through the line *A B*, Fig. 127, is given in Fig. 128. The mold is parted on the level *c c*, and the boss, and the inside and the outside flanges, will be made with dry-sand cores, the three core boxes being shown in Fig. 130. The boxes shown at *h* and *l* have their nearer ends removed so as to illustrate the internal construction.

Fig. 129 illustrates a section view of the rim *g*, and the top outside flange and web patterns *e*. The boss *a*, however, would prevent the pattern from being removed from the mold, and even if *a* were made loose it could not be taken out through the narrow space made by the thin side of the pattern *g*. To overcome this difficulty the boss *a* is made in the core box *l* and the core is bedded in, as shown at *l* in Fig. 131.

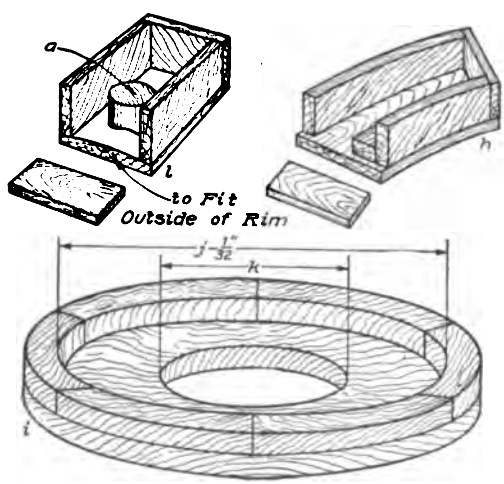


Fig. 130. Core Boxes for Fig. 127

Referring to Fig. 131, which is a section through the vertical center of the pattern, the molding process is as follows: A level bed *d d* is struck off, and the core *i* is located on this bed or surface at the center of the flask. Over this core are placed the rim *g* and the required number of outer-flange cores made in core box

h. The core for the lug *a* is next put into its proper location, shown at *l*, and the mold is rammed to the top of the rim pattern. The sand inside the rim pattern is struck off level, and the web *e* is placed in position and rammed down so as to fit the rim into the groove on the under side of the web. The mold is now filled level with the upper side of the web *cc* and the parting made. The cope mold is now made, and, after being removed, the pattern is drawn. The disk *e* is removed first, and then the rim *g*, when it will be seen that these dry-sand cores, in connection with the pattern, form a mold which will give the casting required.

Examples in molding practice could be multiplied indefinitely, but the foregoing, we think, will give such suggestions as will enable

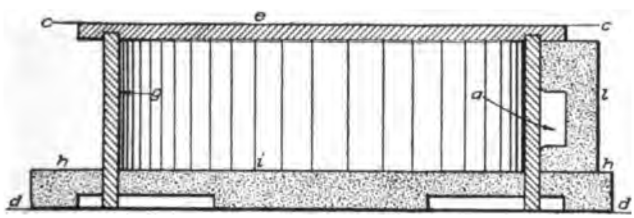


Fig. 131. Section through Vertical Center of Pattern for Fig. 127

the beginner in pattern making to construct all ordinary patterns so that they can easily be removed from the sand without injury to the mold.

USE OF DRAWINGS

Construction Conditions. As already explained, the pattern maker must understand working drawings in order to construct patterns from them directly. These drawings are usually made to a scale much less than the actual size of the required work, and always represent the completed or finished machine or one of its parts.

Drawings are made for the machine shop to guide the machinist in cutting, turning, planing, and fitting the parts given, so as to produce in the castings the shapes, sizes, and general requirements of the articles to be constructed. Hence there is less liability for mistakes after the castings reach the machinist, as he has before him not only the drawing with its accurate dimensions to work

from, but also the castings for the machine or its parts, from all of which the construction and uses of these several parts can easily be understood.

On the other hand, the pattern maker, with the aid of the same drawing, must imagine the casting before him, and must build something in wood which will produce that casting in metal. This pattern, in some cases, will be a duplicate of the required casting, but more often it has only a general resemblance to it, with core prints attached, and is external only, with nothing to show the internal openings, chambers, and winding passages that must be provided for by coring. The core boxes, in which the cores are to be formed, are not shown in the drawings furnished to the pattern maker, but must be provided by him in correct shapes and sizes, in addition to the pattern itself with its added core prints.

In building a pattern the workman, as before stated, must allow for shrinkage. He must also allow for draft and for finish.

Stock Allowances

Shrinkage. The shrinkage of cast iron when cooling in the molds is, as has before been stated, about $\frac{1}{8}$ inch to each foot, and the manner of obtaining the exact sizes for different parts of the pattern has been explained in the section on Measuring Tools. For brass or bronze castings a greater allowance must be made, averaging $\frac{3}{16}$ inch to each 12 inches. Shrinkage rules for brass allowing $\frac{3}{16}$ inch to the foot can be obtained, and must be used for all patterns made from brass.

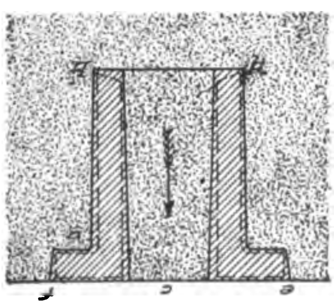


Fig. 132. Allowances in Molding Gland

Draft. After shrinkage, the second point of importance in a well-made pattern is draft. By the term draft is meant the bevel or taper made on all vertical parts of the pattern so that it can easily be lifted from the sand without injury to the mold. This is best illustrated as in Fig. 132, in which it will be seen that if the diameter of a pattern at *a* were to be the same as that at *b*, the latter point would drag over the whole length of the sand until it reached

the former point. As the sand is held together only very lightly, this dragging would be likely to dislodge some of the particles and make it necessary to mend the mold. In order to avoid this, the diameter at *a* is made slightly greater than at *b*, so that the body of the gland is tapering, and the moment it is started out the whole surface from *a* to *b* is clear of the sand and can be removed without injury thereto. This difference in the diameters at *a* and *b* is called the *draft* of a pattern.

Variation. The amount of draft depends upon the length of the part that is to be drawn out of the sand. The allowance for draft, which varies with the pattern, is often greater or less on different parts of the same pattern. For example, the draft on the outside of the pattern of a pulley rim, 24 inches in diameter and

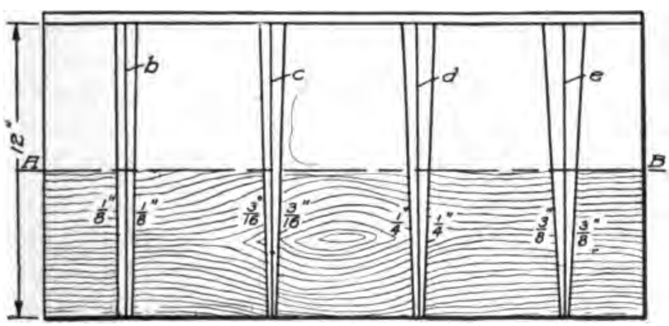


Fig. 133. Draft Template

6 inches face, should be $\frac{1}{8}$ inch to the foot, while on the inside of the rim and on the hub of the pulley it should be in the ratio of $\frac{3}{8}$ inch to the foot. The reason for this difference is that the face of the rim is often turned and finished straight, and for that reason the least possible amount of draft which will allow of the pattern being removed from the sand should be used, while on the inside of the rim a greater amount of draft is necessary if the inside of the pulley mold is to be coped to the center of the arms. This mass of sand hanging from the cope is lifted or drawn from the pattern with the cope flask, and will require a greater draft to be sure of obtaining a perfect lift.

Draft Template. To obtain any required amount of draft correctly, a draft template, kept with other tools and templates,

will be found convenient and useful, saving much time when changing from one ratio of draft or bevel to another. It is made as follows:

Take any straight-grained board 14 inches to 16 inches long and 12¼ inches wide, as shown in Fig. 133. Having jointed the edge *a* perfectly straight, draw the line *b* perpendicular to the edge and 12 inches long, using a steel square and a sharp-pointed knife—not a scratch awl or a lead pencil. On the edge *a* carefully measure ½ inch on each side of *b;* and at the upper extremity, with the same care, measure ⅝ inch on each side of *b;* connect the last two points thus found with the first two on the edge *a* by a sharp knife line, and the result will be a right and a left slanting line, each having, with reference to the perpendicular, a slant of ⅛ inch to a foot. These lines should each be marked "⅛ inch", as shown in the drawing.

Now draw a second perpendicular *c*, at a distance of 1½ inches or 2 inches from the first. On the edge of the board *a* again carefully mark off ¼ inch on each side; at the other extreme mark off $\frac{7}{16}$ inch on each side of *c*, and again connect the latter points with the former. The result will be a taper of $\frac{3}{16}$ inch to a foot. Again repeat the process, making the taper ¼ inch, and lastly ⅜ inch, to a foot. Mark the pairs of right- and left-hand tapers, "⅛ inch", "$\frac{3}{16}$ inch", "¼ inch", "⅜ inch", respectively, as shown. These lines having been obtained permanently, the width of the board may be cut down from 12¼ inches to 6 inches, as shown by the dotted line *A B*, and the board then shellacked.

To use this template, place the bevel against the edge *a* of the board, and carefully adjust the blade to the ⅛-inch, $\frac{3}{16}$-inch, or other draft, right or left, as may be required. It will readily be seen that whatever may be the width of the surface to which the bevel is applied, the taper or draft will be the exact proportion of the given amount for each 12 inches.

Finish. In pattern making, the term *finish* refers to the additional thickness besides shrinkage and draft, which must be given the pattern in places where the casting is to be planed, turned, chipped and filed, or fitted, in the machine shop. The amount that is to be so added is, to a certain extent, though not wholly, independent of the size of the piece. For small articles whose longest dimension does not exceed 3 or 4 feet, an addition of ⅛ inch to the surface to be finished is usually sufficient. For larger dimen-

sions it may be necessary to add as much as ¼ inch or ⅜ inch, but very rarely more than this. In making this allowance it is also well to bear in mind the tendency of the casting to warp in cooling. Where the thickness of the metal varies to any great extent, there is a greater liability to warp than if a uniform thickness prevails

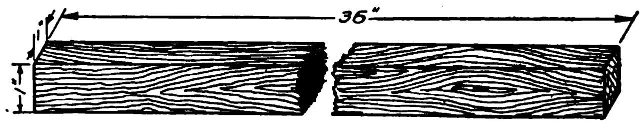


Fig. 134. Pattern for Plain Bar

throughout the whole. Hence, in such cases, a greater allowance must be made for the finishing.

On small pieces, and where the molding is carefully done, it may be possible to make as small an allowance as $\frac{1}{16}$ inch, but as a general rule sufficient metal should be put upon the casting to allow the cutting tool of the finishing machine to cut well below the surface so that it shall not become dulled by the sand and the hard scale on the outside.

Example of Allowance. A pattern for the plain cast-iron bar illustrated in Fig. 134 will afford a good example of the allowance necessary for finish and for draft. This bar is to be finished all over, the finished sizes being 36 inches long, 1 inch wide, and 1 inch thick. A slender bar of this length is liable to warp or bend when cooling in the mold, and for this reason the bar should have an allowance of at least ⅛ inch all over for finish, thus requiring a pattern 36¼ inches long, 1¼ inches wide,

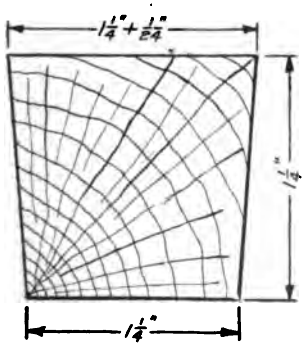


Fig. 135. Allowances for Finish and Draft

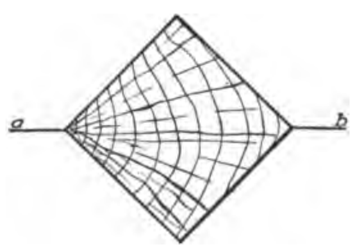
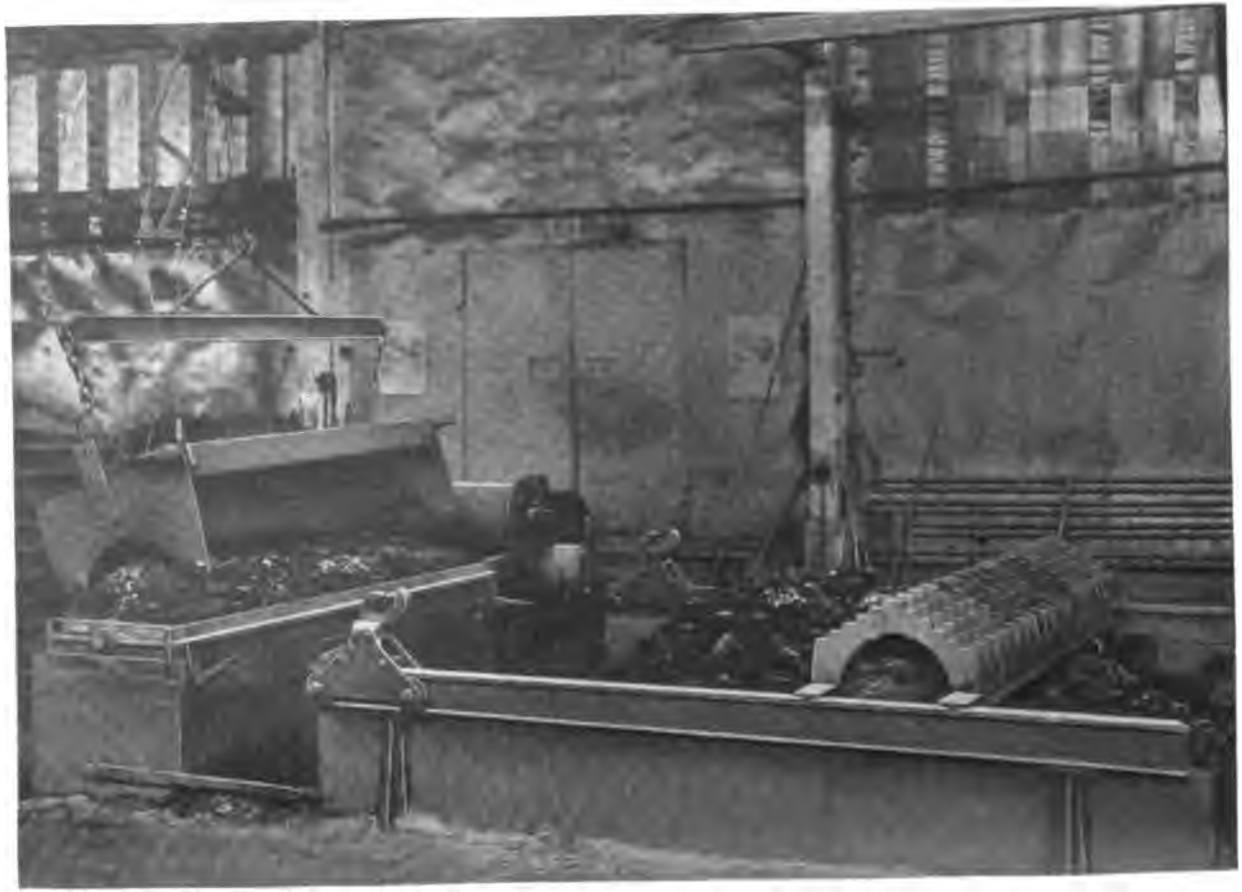


Fig. 136. Position for Molding without Added Draft

and $1\frac{1}{4}$ inches thick—actual dimensions. Moreover, to enable the molder to remove the pattern from the sand without injury to the mold, we must add on two of the opposite sides a draft of about $\frac{1}{4}$ inch to the foot, making a cross-section through the pattern of the shape and dimensions shown in Fig. 135.

When accuracy is required in testing bars—1 by 1 by 36 inches, and seldom finished—they are often molded partly in the cope and partly in the drag, as shown in Fig. 136, the parting being on the line *ab*. In this position the inclination of the sides of the pattern in the mold is so great that no draft is required, the pattern being simply a square bar of wood of dimensions 1 by 1 by 36 inches, measured with the shrinkage rule.



MOLDAR SAND SHOVEL DEPOSITING SAND IN FLASK

PATTERN MAKING

PART II

CONSTRUCTION OF PATTERNS

SIMPLE TYPES

Conditions of Procedure. Whenever the building of a pattern is consigned to the pattern maker, a detailed sketch or drawing of the completed casting should be furnished; also information regarding the number of castings that are required. It may be a repair part, or experimental work, and only one casting required, and, if so, it would often be economy to make the pattern as cheaply as possible, even if the expense of molding is slightly increased. Or it may be for a standard casting, for which it is expected to use the pattern for years, and in this case special study should be given the manner of construction, to prevent the distortion and general breakdown of the pattern, due to its shrinking, warping, and abuse.

INFLUENCE OF MOLDING METHOD

One-Piece Patterns

Green-Sand Coring. The simplest patterns are those which are made in one piece, and which require no coring, although the castings themselves may be hollow. Deciding the method of molding indicates the way in which the pattern is to be removed from the sand, and where the parting line of the pattern, if there is one, should be. As an example of a simple pattern of one piece made without a dry-sand core, the stuffing-box gland shown in Fig. 132, Part I, is a good illustration. It is readily seen that, if the pattern of such a gland were to be imbedded in the sand as shown, there is no reason why it could not be lifted out without disturbing any of the surrounding or the internal sand. The drawing represents the pattern with draft and finish added, the finished gland being shown by the dotted lines.

Core. Any part of a mold which projects far enough into the cavity to form a hole or recess in the casting is called a core, whether it is formed by the pattern or is placed in the mold after the pattern is drawn. In the case where the core is made by ramming the molding sand—called green sand—into a recess in the pattern, it would be known as a green-sand core, as shown in Fig. 132, Part I.

The use of the green-sand core is limited to cores of comparatively short length and large diameter. To illustrate: A pattern designed for a green-sand core 2 inches long by $\frac{1}{2}$ inch in diameter would be very difficult to draw without lifting or breaking the core, and also the inrushing molten metal would wash away some of the core—for a green-sand core of these proportions cannot be rammed very hard and permit drawing the pattern, although a pattern with a core of this kind $1\frac{1}{2}$ inches in diameter and 2 inches long could be easily drawn and it would have sufficient strength to withstand the pouring process. A green-sand core of comparatively small diameter, should have more draft than those of larger diameter which should have a draft of $\frac{1}{8}$ inch per foot, this being the usual draft allowance for the outside of patterns.

Typical Construction. In order to give a better understanding of the methods employed in pattern making, the object itself will be illustrated, and when it is to be finished, the finished dimensions only will be given. If the object is not to be finished, the sizes of the completed castings will be shown. These dimensions will, in all cases, be arbitrary, and may be changed at will, if for any reason alteration is necessary. The successive steps in the construction of the pattern are given in detail so that the student may fully understand the principles involved.

Dry-Sand Cored Bushing. The first article for consideration is the brass bushing flanged at one end, illustrated in Fig. 137. This bushing is to be finished all over, and as the casting is small, $\frac{1}{16}$ inch will be sufficient for outside finish and the same for turning out the inside. On examining it with regard to molding, we find that if molded on end with the flange up and on the parting line of the flask it can be readily removed from the mold. In making the mold from this pattern, the cylindrical hole in the casting will be made by the use of the dry-sand core as described in the section on Molding Practice in Part I.

The draft in this instance should be $\frac{1}{8}$ inch per foot. It is well to have standard dimensions for the core prints for reasons explained subsequently relative to standard core prints. The lower core print should have the same proportion of draft as the body of the pattern,

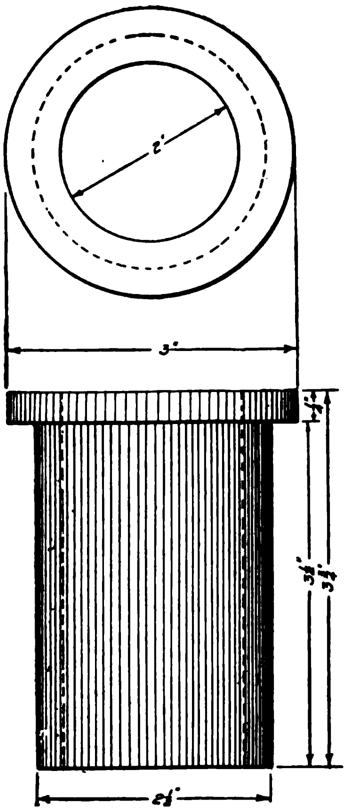


Fig. 137. Finished Bronze Bushing with Flange at One End

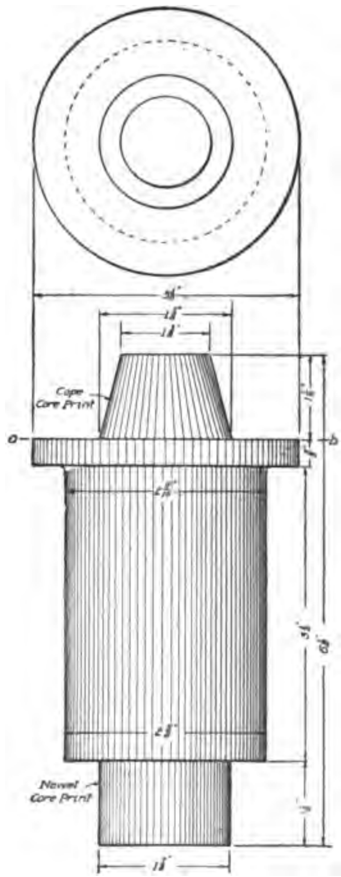


Fig. 138. Plan and Elevation of Pattern for Bronze Bushing

but the upper core print is given the excessive draft of $\frac{3}{16}$ inch to its length so that the cope can be easily lifted off and returned again over the tapering end of the dry-sand core without injury to the mold; the parting of drag and cope being on the line *ab* at the flanged end of the bushing.

Having the finished sizes given, as in Fig. 137, and having decided on the amounts of draft and finish, the pattern will be as represented by Fig. 138. In the case of this simple pattern, as in all others, a full-size drawing, or sketch, giving all the dimensions of the pattern, should be made by the pattern maker before beginning work on the pattern; this is good practice, and, if carried out, many mistakes and much loss of time will be avoided.

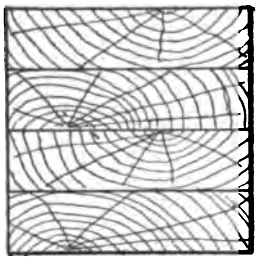


Fig. 139. Glued Stock with Heart and Bark Sides Reversed

Shaping Pattern. This pattern may be turned from a solid block of wood, but if durability is desired, the block should be glued up from 4 pieces of $\frac{7}{8}$-inch pine, care being taken to reverse the annular rings or yearly growth of the wood, as shown in Fig. 139. Place the block in the lathe and with the gouge turn to a cylindrical form of slightly greater diameter than the largest diameter of the pattern, say $3\frac{3}{16}$ inches.

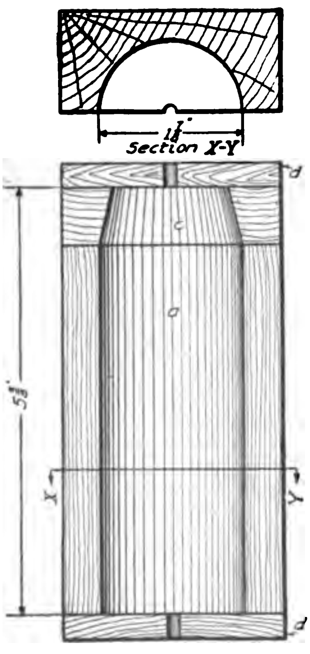


Fig. 140. Core Box for Bronze Bushing of Fig. 138

Finishing to diameter should be done by the use of scraping tools. For the body of the pattern, a firmer chisel 1 inch wide is a good tool, but the cutting edge must be ground and sharpened slightly rounding, as described for plane irons; otherwise the corners of the tool are liable to catch and form grooves on the surface. For turning the ends to size, use the right- and left-hand skew chisels, not with a scraping cut, but holding the chisel with its edge nearest the point resting on the tool rest.

Forming Core Box. The core box for this pattern is shown in Figs. 140 and 148, which are representative of the half box used for all symmetrical cores. In this box, two semicircular or half cores are made, which, after being baked in the core oven, are pasted together, first having a

small groove scratched along the center of the flat side of each half, to form a vent for the gases generated during the pouring. A small V-notch, as seen in Fig. 148, should be cut at the center of each end of the half-core box to assist in making this vent.

Gouging Cylindrical Section. For the part *a* of the core box, a block of slightly greater length ($\frac{1}{2}$ inch or 1 inch) is first planed up to the exact size. A center line, shown at *b*, Fig. 141, is drawn with the marking gage parallel to one of the edges, and also extends across each end of the block. From this center line, at a distance of $\frac{15}{16}$ inch on each side, the lines *d* and *e* are also drawn. Then, with a second block or strip of wood placed against the face of the block and flush with the end, the two pieces are clamped together in the bench vise, as shown in Fig. 142. Now, with the dividers adjusted to $\frac{15}{16}$ inch, describe on each end of the block the semicircle which connects the lines *d* and *e* on the ends of the block. This wood may be removed rapidly with a gouge and mallet, smoothed with a round plane of proper size and curve, and finished by sandpaper rolled on a cylindrical block having a diameter $\frac{3}{16}$ inch less than the width of the required box.

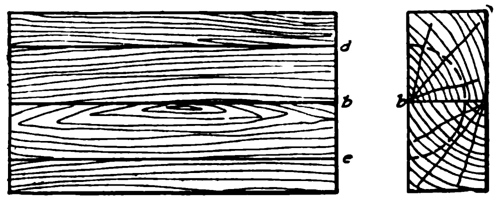


Fig. 141. Core-Box Stock with Construction Lines

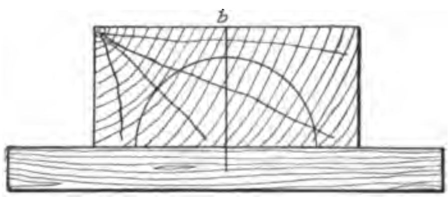


Fig. 142. Layout of Box before Gouging Cylindrical Section

As the work progresses, the accuracy of the curve is tested by means of a try-square or other 90-degree angle, as shown in Fig. 143.

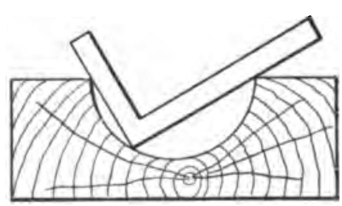


Fig. 143. Right-Angle Test of Circle

Right-Angle Methods. Another method frequently used for small boxes, is to work out the center of the curve with a rabbet plane, forming a right-angled opening, as shown in Fig. 144, the

remaining wood being removed with the round plane and finished with the cylinder and sandpaper as before.

If the machine-saw table can be tilted, as in Fig. 97, Part I, a cut similar to that in the previous method can be made, Fig. 145.

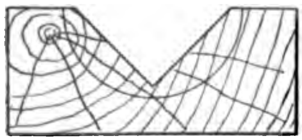


Fig. 144. Rabbet-Planed Opening

Turning Tapered Section. The tapered end of the box *c*, Fig. 140, is turned from a block of wood, screwed to the faceplate of the lathe, as shown in Fig. 146. After the hole is turned to the required $\frac{3}{4}$-inch depth, and to the required $1\frac{7}{8}$-inch size on the outside, and to $1\frac{5}{8}$ inches at the bottom, it is removed from the faceplate and the piece *c* is cut out, as shown by the dotted lines in Fig. 146. This piece *c* is glued and nailed to the end of *a*. The two ends of the box are now given a slight draft—$\frac{1}{4}$ inch in 12 inches—to allow the half core to leave the box easily. The end strips *d* and *d*, Fig. 140, are then nailed on, and the box is complete.

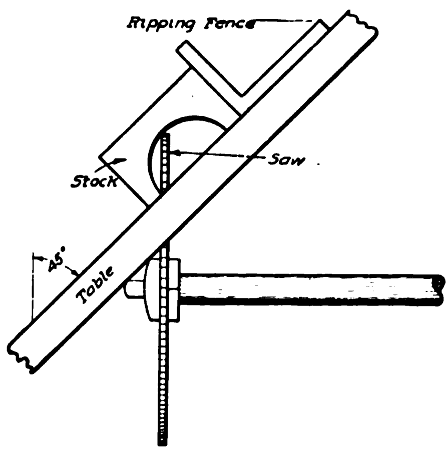


Fig. 145. Skeleton View of Machine Saw with Table Tilted to 45 Degrees

Approved Process. While taking up the construction of this core box for a cylindrical dry-sand core, it will be well to consider other methods of procedure, and herein lies one of the engineering features of the trade—to be able to discern which method is best adapted to the requirements.

Another method which has some advantages is that shown in Figs. 147 and 148. Select stock with a width of about 1 inch greater than the diameter of the required core, with the depth about half this width, and the length slightly longer than the total length of the pattern, including the core prints *h*. Dress this stock to a parallel thickness and width. Scribe a center line with the marking gage on one side, and cut one piece *d*, Fig. 148, for the cylindrical part of the core—the length *b* to include the length of

the nowel core print—and cut another piece *e* to the length *c* of the cope core print.

The waste in the semicylindrical hole in *d* is to be removed as follows: Make two machine-saw cuts, as at *i*, Fig. 147, about $\frac{1}{16}$ inch deep, and locate them so as to have the outside edge equal the diameter of the required core *a*. Cut out the remaining stock as shown, so as to be able to break out the stock left standing. Remove the remaining stock with the core-box plane, as described in the section on Hand Cutting Tools in Part I.

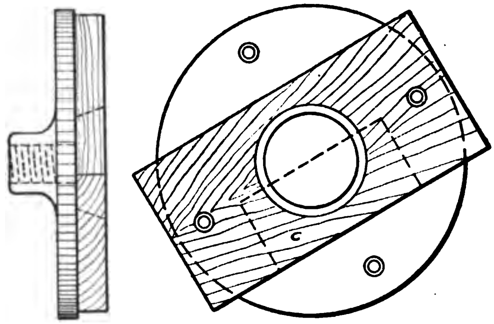


Fig. 146. Cope End of Core Box Mounted on Faceplate for Turning Tapered Section at *c*, Fig. 140

Scribe semicircles on piece *e*, Fig. 148, for the large and small ends, to correspond to the dimension of the cope core print. If there is a $\frac{1}{4}$-inch band saw, tilt the table and saw to these lines, or remove the stock with a gouge. In either case, finish smooth on a small sand roll, unless the hole in the *e* section is very small, when it should be finished by hand. Size the ends of *d* and *e*, and glue together. As soon as the glue is set enough to allow handling, nail the ends *f* on, and cut the grooves *g* with the machine saw and glue a spline of soft wood in each. Machine-saw a slight amount of stock from the side and ends to clean the outside. A narrow chamfer should be planed on the outside corners, but no other work done to the outside. The advantage of the spline is, that if the core box is to be altered, by sawing out the spline the box is easily broken apart, and the spline replaced after the changes are made.

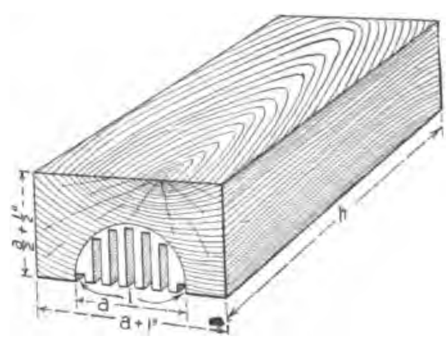


Fig. 147. Method of Removing Waste Stock

Finishing. *Shellacking.* Having completed the pattern and its core box, the surface of the wood must be covered with some material which will render it hard, smooth, and impervious to the moisture in the sand, and at the same time make it easier to be withdrawn from the mold. Pure grain-alcohol shellac varnish is the best for this purpose. All cheap substitutes, such as wood-alcohol shellac, or copal varnishes should be avoided; they become flaky and scale off, and do not stand the exposure and moisture. Pattern makers generally make their own shellac varnish, buying only the best quality of shellac gum, and using 95 per cent proof alcohol. The proportions are 3 pounds of gum to 1 gallon of alcohol. The gum is put in a wide-mouthed bottle, or earthen jar, and the alcohol poured over it; and, if well stirred three or four times during the day, this will—if the alcohol is of the best—give a smooth clear orange-colored varnish, ready for use.

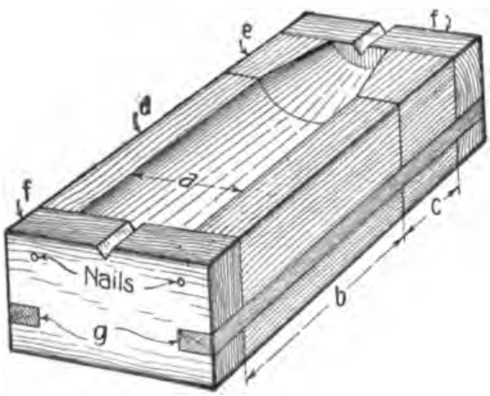


Fig. 148. Completed Core Box

A good grade of white grain-alcohol shellac may be made from bleached gum, or can be bought from the dealers, but it dries more slowly and does not produce so hard a surface as the orange shellac. Orange or white shellac varnish should never be kept in a metallic can or cup, as the oxidation of the metal will discolor the varnish.

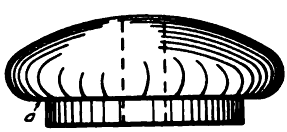


Fig. 149. Wood Cover for Shellac Pot

As the alcohol in shellac varnish evaporates very rapidly, the brush should be kept in a vessel which is closed and air tight. A short bottle having a mouth wide enough to admit the brush is best for this purpose. A 1-inch flat double-thickness fitch hairbrush is good for general work. Do not use a cork, but turn a wooden cap for the bottle, such as is shown in Fig. 149, and of which the shoulder at *a* may be $\frac{3}{16}$ inch to $\frac{1}{4}$ inch

long, but must be at least $\frac{1}{4}$ inch less in diameter than the inside of the mouth of the bottle. Otherwise the shellac will cement it to the glass so that it cannot be removed. Its only object is to keep the cap nearly central on the bottle. The handle of the brush must be tightly fitted into a hole through the center of the cap and fastened with a screw or brad, allowing the brush to reach within $\frac{1}{2}$ inch of the bottom of the bottle. Keep the bottle one-third to one-half full of shellac, and use the brush with the cap on the handle. The shellac will make a tight joint between the bottle and the cap, and, if the proper amount of shellac is kept in the bottle, the brush will always remain soft.

For small patterns, such as the bushing described, the small quantity of shellac needed can be used directly from the bottle. For large work, however, an earthenware cup or mug should be used, but the shellac left over should always be returned to the vessel in which it is kept.

Sandpapering. Having given a perfectly smooth surface to the pattern and core box by the use of very fine sandpaper—No. 0—apply the first coat of shellac. This first coat will raise the grain and roughen the surface of the wood, which, after the shellac is perfectly dry, must be sandpapered a second time until smooth. Now apply a second coat. Should there still be roughness, a second sandpapering will be necessary. At least three coats of shellac should be used. If there is much end wood exposed on any of the surfaces of the pattern, a fourth coat may be necessary on these parts.

Coloring. As regards the color in which patterns are finished, there are different rules in different shops. The general rule, however, is to leave all patterns for brass or bronze in the natural color of the wood, and to shellac the core prints red. If the pattern is intended for molding cast iron, the body of the pattern is made black and the core prints red. The parts of the core box in which the core is to be formed are also colored red and the outside of the core box black. The black color is produced by mixing lampblack with the shellac varnish, and the red color by mixing vermilion—Chinese is the best—with the shellac. The vermilion is heavy and will settle, hence it must be stirred or well shaken before using. The best method is to first use two coats of the natural colored shellac—

orange or white—on all surfaces of the pattern, core prints, and core box, then apply the black or red for the last coat only.

As the pattern already described is for a brass bushing, the body should be left the natural color of the pine, and the core prints on the pattern and the inside of the core box colored red. The outside of the core box may be left the natural color or made black, as preferred. The outside of the core box, having no part in the formation of the core, is not necessarily so well and smoothly finished as the inside.

Final-Finishing. All nail holes or any defects in the wood should be filled with beeswax applied with the warm blade of a knife, or narrow chisel, warmed by holding in hot water. The beeswax should always be used after the first coat of shellac has been applied, as it will then hold better. The sandpapering of the pattern, after the first coat, will smooth the wax and bring it even with the surface of the wood. The time required for a coat of shellac to dry is from 8 to 12 hours, depending upon how heavily it may have been applied, even though to the touch the surface may seem dry in 1 or 2 hours. If a hard durable surface is required on the pattern, 12 or better, 24 hours must be given between each coat. The roughness will then sandpaper off as a dry powder without gumming the sandpaper, and leave a hard smooth surface for the succeeding coat of shellac.

Split Patterns

Conditions. The second casting to which attention is called, is the brass bearing represented in Fig. 150, which is to be finished all over. On examining the drawing, first with regard to removing the pattern from the sand, we find that it must be molded on its side, and, that the molder may not lose the time required in cutting away the sand, as in Figs. 112 and 113, Pattern Making, Part I, the pattern must be parted or made in two halves. For finish on this small pattern $\frac{1}{16}$ inch will be sufficient, and draft will be required only on the ends of the pattern and on the ends of the core prints, which, in this case, should be not less than 1 inch long. This is necessary because the core-print molds must sustain the weight of the dry-sand core.

Method of Making. The pattern for this casting is represented by Fig. 151, in which it is seen that, unlike Fig. 138, the body

and core prints are perfectly straight, a slight draft—$\frac{3}{16}$ inch in 12 inches—being given to the ends only of the pattern and to those of the core prints. A slight curve of $\frac{1}{16}$-inch radius should also be made at the intersection of the body of the pattern and the inside of the flange at *aa*. The wood in being prepared for this pattern should be cut $2\frac{1}{2}$ inches longer than the finished pattern. The dimensions of the two halves would each be $1\frac{3}{4}$ by $3\frac{3}{8}$ by $8\frac{3}{4}$ inches.

Having fitted the two insides accurately together, and dressed one

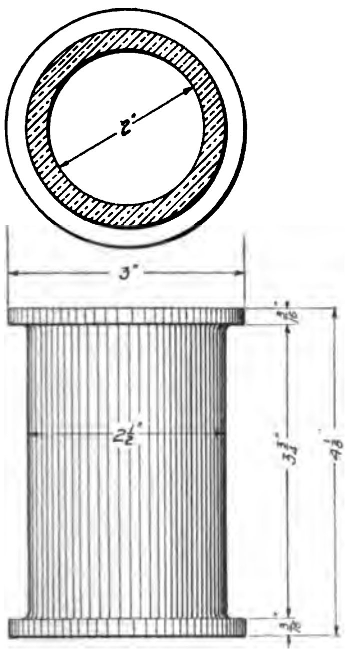


Fig. 150. Finished Bronze Bearing Flanged at Both Ends

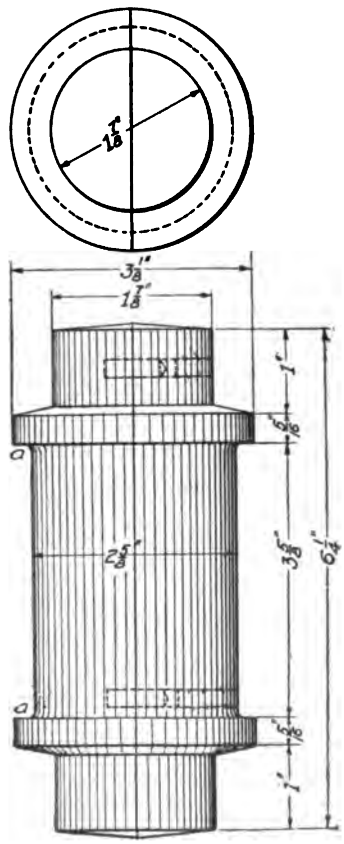


Fig. 151. Pattern for Bushing, Fig. 150

edge of each straight and at right angles to its face side, with the marking gage draw a center line on each, not only on the face but also across each of the two ends, Fig. 152. Place about $\frac{1}{2}$ inch of the pointed end of a $1\frac{1}{2}$-inch wire nail on the center line, as shown in Fig. 152, and, striking it with a hammer, make an indentation at each end of both pieces of stock to form the location of the head-

stock and tailstock lathe centers. Glue $\frac{3}{8}$ inch of the joint at each end, and clamp the stock together, being careful to keep the ends and the edges of the stock flush with each other. At the ends insert two metal corrugated fasteners, as shown in Fig. 153, placing them near the center of the end, but not so as to come in contact with the lathe centers. Drive a nail into the center hole in each end to force out the glue, for, if the glue should harden, it would be impossible to center the stock in the lathe.

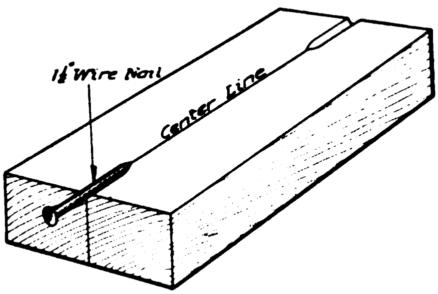


Fig. 152. Preparing Stock for Split Lathe Work

Doweling. The dowel-pin holes should be drilled before the stock is turned to a cylinder so as to have them stand perpendicular to the joint. The location of the dowel pins should indicate which way the parts go together. If it is attempted to so locate the dowel pins that the parts can be assembled either way, it is very likely that they will not assemble accurately both ways—and when the nowel part of the pattern is in the mold it is not so easy to tell which way is correct—so, unless the core prints are quite small, locate one dowel pin in the core print and the other in the body of the pattern, as shown in Fig. 154. They could also be located to one side of the center line, if it is not desirable to put them in the core print. The dowel pins should be placed as far apart as possible to prevent side slip of the pattern when the dowel pins and holes have become worn. Mark on one side of the stock the form of the pattern to show the location, and drill $\frac{1}{4}$-inch holes through the upper half of the stock and to a depth of about $\frac{1}{2}$ inch into the lower half. The dowel pins need not be inserted until after turning. Glue a pin in

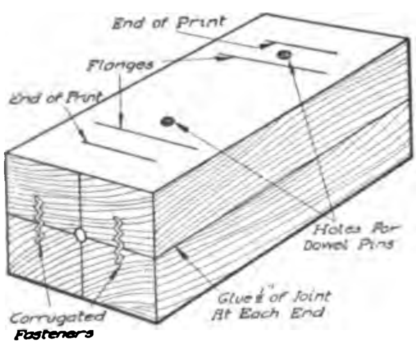


Fig. 153. Split Stock Ready for Turning

the holes drilled just deep enough to have the surface of the pattern turn smoothly. These pins should be made of the same stock as that used for the pattern. The dowel pins should always be inserted in the hole having a bottom, so that the pin cannot be driven below

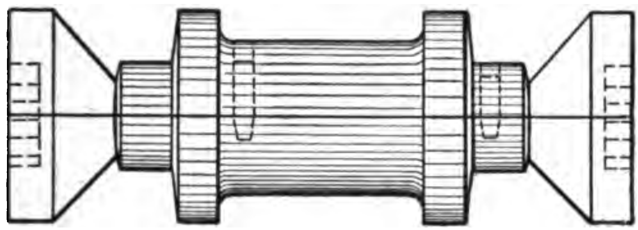


Fig. 154. Split Bushing Pattern Ready to Take from Lathe

the proper height, and should always be placed in the cope part of the pattern, as in Fig. 151.

Care Required. When centering the stock in the lathe, great care must be taken that the spur on the centers enters the small hole left in the ends of the stock exactly on the parting line of the pattern. Fig. 154 shows the pattern as ready to be taken from the lathe. Saw off the waste stock, trim the ends true with a chisel, and sandpaper smooth. Shape the hardwood dowels to the proper form, Fig. 155, and, after gluing them in place, clean off any excess glue. These dowel pins will always bring the parts into accurate alignment when used by the molder in the foundry. Before removing the turned pattern from the lathe, it should be smoothed and finished with sandpaper, but care must be taken not to allow the sandpaper to come in contact with the sharp corners and angles of the pattern, or they will be rounded off and the work ruined. For pine, only the finest paper—No. ½ and No. 0—should be used on lathe work, and the paper must not be held in one position on the revolving work but must be kept moving laterally, that is, from side to side, to avoid

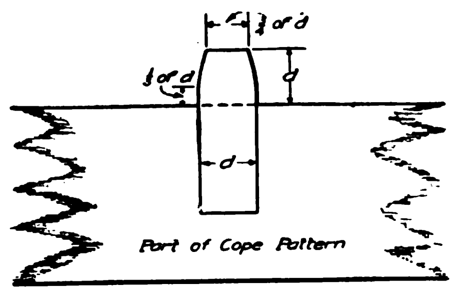


Fig. 155. Diagram Showing Proper Proportions of a Dowel Pin

cutting depressions in the surface. When the scraping tools are kept sharp so that they cut freely and without pressure, a light touch of sandpaper only is required.

Construction for Durability. In the construction of this pattern, it may be made of two blocks of 1¾-inch stock as described, but the tendency of the two halves will be to become rounding on the parting line, as shown by the dotted lines *cd* and

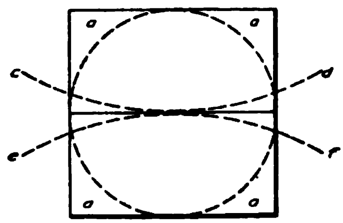


Fig. 156. Diagram Showing Tendency of Pattern Stock to Warp

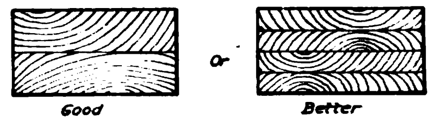


Fig. 157. Method of Gluing Stock to Prevent Trouble Shown in Fig. 156

ef, Fig. 156. This is caused by the removal of considerable wood in the process of turning, at the angles *aaaa*, thus exposing fresh surfaces which are farther removed from the original surfaces of the plank than the surfaces on the line of parting. The exposure of these deep inside fibers of the wood will cause a shrinkage of the pores and draw the pattern more or less, according to the position

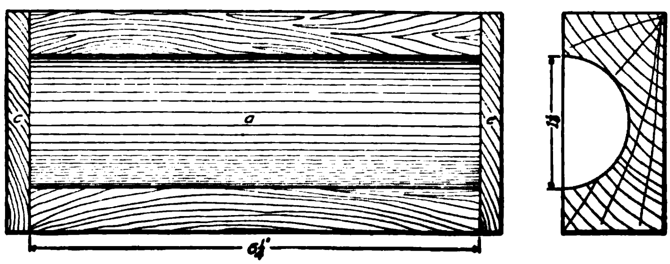


Fig. 158. Core Box for Pattern, Fig. 151

of the annular growths, and also to the more or less thorough seasoning of the wood, in the direction indicated.

If the pattern is intended for temporary use only, it may be constructed as above; but if durability and permanence of shape are required, the two blocks should each be glued up out of thinner stock, with the annular growths carefully reversed, as shown in Fig. 157. This is done not only because thin plank is more evenly and better seasoned, but because in gluing, the tendency of the

pieces to warp or spring is counteracted each by the other, and, in addition, the gluing of several thin pieces together stiffens and makes the resulting piece much firmer and stronger than a large block or piece of the same size obtained without gluing.

Core box. The core for this pattern being straight from end to end, and cylindrical, only a half-core box is required, as shown in Fig. 158. After being laid off and worked out in the same manner as described for the core box, Figs. 140 and 141, cut the ends of *a* with draft of $\frac{1}{4}$ inch in 12 inches, and glue and nail on the ends *c* and *e*, which may be $\frac{3}{8}$ inch to $\frac{1}{2}$ inch in thickness.

Finishing. Shellac and finish as described for the pattern in Fig. 138, giving first two coats of orange or white shellac, and for the last coat on the core prints of the pattern and the inside *a* of the core box use the red, the body of the pattern being left natural color —with three coats—and the outside of the core box either natural or black.

FASTENING PROCESS

Gluing. As the use of glue enters largely into the construction of all patterns, some instruction as to its selection and the manner of using is necessary. When building up patterns, the connections should in all cases be made by gluing.

Use of Nails. Nails should never be used except when they can be so placed as to be entirely removed from all danger of contact with the tools used in turning and shaping the pattern, and when so employed should be used in conjunction with glue. The only advantage in their use is the hastening of the work, because they take the place of hand screws or clamps while the glue is drying. The use of nails, however, is always unsatisfactory, for when the point is passing through the upper piece, small thin slivers are broken from the under surface, which have a tendency to separate the two surfaces instead of exerting the required pressure as when hand screws are used.

Kinds of Glue. For pattern work select only the very best quality of cabinetmakers' glue, or better still, the best quality of white glue. This white glue can always be had in two forms: (1) clear; and (2) opaque. The first is the glue without the addition of any foreign substance. The second looks much whiter than the

first, because of the addition of whiting, or other mineral, to the glue. This addition does not in any way lessen the adhesive qualities of the glue; on the other hand, it sets more readily and dries more quickly, but for this very reason it is harder to use on large surfaces, as the first brushing on one part of the work will begin to set before the entire surface can be covered. As this objection does not apply to small or moderate-sized work, however, the opaque white glue is to be preferred in such cases.

Preparation. Good glue will keep in a dry room of any temperature for an indefinite length of time, but when cooked in the gluepot it deteriorates very rapidly. Each successive reheating and boiling lessens its adhesive qualities, hence it should always be used fresh, or nearly so. A greater quantity of glue than is likely to be used in two or three days should not be cooked at one time.

The cooking and preparing must be done in the regular gluepot, made for the purpose, and sold in all hardware stores. No rule can be given for the relative quantities of glue and water to be used. Some glues, especially the cheaper grades, require much less water than the better and finer qualities. As a general rule, however, pack the glue firmly in the pot and add sufficient cold water to cover it. Fill the outside kettle with cold water and boil until thoroughly cooked, so that it will run smooth and clear from the brush or paddle. It should run freely without returning and gathering in bunches or clots at the end of the paddle, but must not be so thin as to be weak and watery.

If the glue is too thick, no amount of pressure will bring the two glued surfaces in close contact, and if too thin there is danger that the joint will not hold. Always use cold water for cooking and dissolving fresh glue. Hot or boiling water will make the glue stringy and will require a much longer time to cook to an even and smooth consistency. Great care should also be taken to keep the outside kettle, which surrounds the gluepot proper, full of water. If allowed to boil dry the glue in the inner pot will be scorched or burned, and will then be entirely useless. It must then be thrown out, the pot washed or boiled out clean, and fresh glue again cooked. The hot water in the outside kettle should in all cases be used for thinning the glue to the required consistency. Cold water chills the glue and necessitates reheating.

Application. In cold weather the precaution must be taken, unless the room is warm and entirely free from drafts, to heat the pieces of wood before applying the glue, else the latter may be chilled and fail to set. The time required for well-made joints to dry so that the hand screws can be removed is from 4 to 6 hours.

Sometimes a difficulty will arise in the case of large surfaces on thin material. When the glue is applied it moistens and expands the surface upon which it is placed, causing the edges to curl up and pull away from the adjoining piece which has a tendency to move in the opposite direction. In such cases never moisten the back of the thin pieces with water from the outside kettle, as is sometimes directed, but, working quickly, spread the glue rapidly, and then place between two thick stiff pieces of board, previously dressed true, prepared and heated for the purpose. Use as many hand screws as can be conveniently placed on the work, and allow it to remain in these clamps until all moisture from the glue is absorbed by the two outside heated boards. Twenty-four, or better 48, hours should be given to this process, if possible.

All such gluing of thin pieces should in every case be done first and allowed to dry while the other parts of the pattern are being constructed. Under no circumstances use water on any surface of seasoned wood. The reseasoning or drying out of such water will invariably distort, curl, and warp the pieces so treated, after being glued together. Even the water contained in the glue is objectionable, while unavoidable, and can be most satisfactorily removed only as directed above.

In all cases where end wood is to be glued, or where the grain of the wood runs diagonally to the plane of the joint so as to present the open end wood pores for the glue, this end wood, or partially end wood joints, should be first sized with thin glue—glue about half the thickness of that used for gluing—and allowed to dry. This will raise the grain and roughen the surface of the joint, which, when dry, must be lightly and carefully scraped off with a sharp chisel, when it will be found that the open pores of the wood are filled with dried glue. The joint may now be glued, and the glue will hold as in ordinary jointing.

Clamping. *Use of Hand Screws.* The hand screws, illustrated in Fig. 79, Part I, Pattern Making, enter so largely into all gluing

for pattern work that some description of their construction and the manner of using is necessary here. The four parts of each hand screw consist of two jaws and two spindles. When using, the jaws must in every case be kept parallel. This is done by the adjustment of the middle or central spindle. The clamping is in all cases done by the outside or end spindle, the middle or adjusting spindle serving as a fulcrum for the jaws, and the leverage and pressure being obtained by the end spindle.

To open and close the hand screws for larger or smaller work, do not screw or unscrew one spindle at a time. Instead, grip the handle of the middle spindle in the left hand, and the handle of the end spindle in the right hand. Hold the hand screw at arms length and whirl it from or toward you as may be needed for closing or opening the jaws. In this way the spindles will each be kept in its proper relative position, and the jaws will, at all distances, remain parallel.

Pressure Regulation. When clamping broad surfaces, care must be taken to see that the pressure of the jaws on the work being glued is the same at the points and at the back part of the applied portion of the jaws. This can be easily changed at will, by slightly loosening or tightening the middle spindle, which, as before stated, is the adjusting spindle and fulcrum, and not used for clamping. After adjusting the jaws parallel and to even pressure on all their length as applied to the work, screw up and tighten the end spindle to the utmost pressure which the jaws will bear, and again examine the clamp and the work to see if the jaws are parallel and the pressure even. If not, loosen the end spindle and readjust the middle spindle by opening or closing as the case may require.

BUILT-UP PATTERNS

Sheave Pulley

Green-Sand Ring Coring. For practical reasons, the first method of molding—for green-sand core, or, in this case, ring—the 6-inch sheave pulley shown in Fig. 159 would ordinarily not be used. The expense of molding would more than offset the alternative extra expense caused by making a dry-sand core for the groove in the outer edge of the sheave. However, consideration of this method is offered at this time solely for the study of the manner of

building the pattern, as it will be found practical to use this process in making numerous other patterns. The study of the molding process is also of value. The molding of this pattern is as explained in connection with the use of the green-sand ring, under Molding Practice, Pattern Making, Part I.

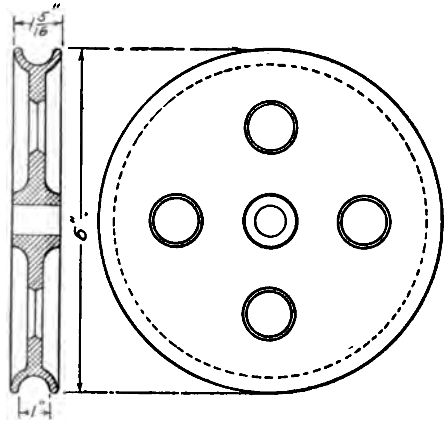


Fig. 159. Small Sheave Pulley

Making Master Pattern. The wood pattern for this casting, molded as described, is comparatively frail, so a working pattern should be made of some aluminum alloy in order that the weight will not interfere with the molding process. The metal pattern should be lathe finished all over; consequently the wood pattern shall include stock for this finish. Allow $\frac{1}{16}$ inch on each surface for this finish, besides the allowance for the aluminum shrinkage which will be about $\frac{1}{4}$ inch per foot. These must be added to the shrinkage allowed for the metal used in the final castings; if the final castings are to be of iron, and the metal pattern made of cast aluminum, the shrink allowance should be based on a shrinkage of $\frac{3}{8}$ inch per foot. The wood pattern is called the *master pattern.*

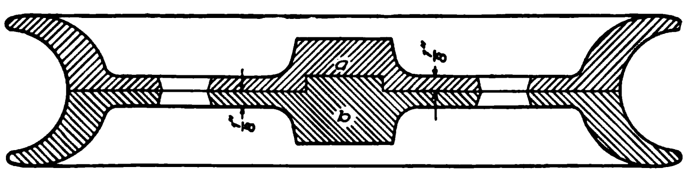


Fig. 160. Section of Pattern for Sheave

A cross-section through the finished pattern for this casting is shown in Fig. 160. The groove is a semicircle 1 inch wide, and the rim containing the groove is connected with the hub by a solid web $\frac{1}{4}$ inch in thickness and having four or six holes, each 1 inch in diameter, this web taking the place of arms. If there is to be no finish on

the sheave, as is usual, the only allowance to be made on the pattern, which must be parted, will be for shrinkage and for draft.

Segmental Construction. In all patterns of this kind, the web is first glued up in sectors, Fig. 161, six, eight, or more in number, according to the size of the sheave. The sectors are fitted by hand or on the trimmer, the ends are glue sized, and when the sizing is dry the joints are carefully scraped smooth and the whole glued together. After drying for 4 or 5 hours, it is sawed to a circle of $\frac{1}{2}$ inch greater diameter than the finished pattern, and the block for the hub is glued over the center. Six segments to form the outer rim are glued around on the outer edge, care being taken to break joints, as shown in Fig. 162. If the groove is to be large, the six segments should be of half the thickness only, and a second set of segments of like thickness glued over the first, breaking joints not only with the first set, but also with sectors of the web. In other words, in all glued-up rims, no two joints should be directly over each other. All joints

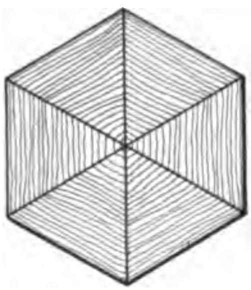


Fig. 161. Segmental Construction of Web for Sheave Pattern

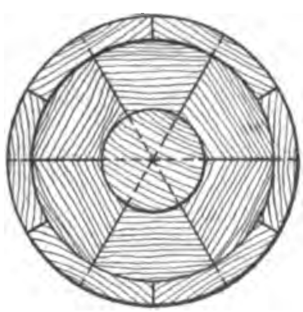


Fig 162. Web with Rim Glued On

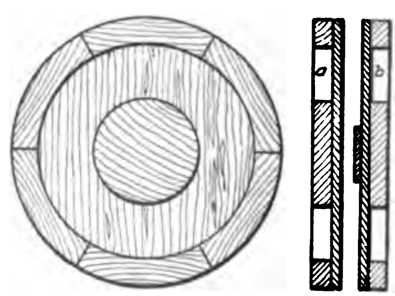


Fig. 163. Construction Views of Sheave Pattern

must be so broken and so distributed as to give the greatest possible strength to the rim.

In the present case, our pattern is so small that it is only necessary to use a thin board $\frac{1}{4}$ inch in thickness for each half of the web. After sawing to $6\frac{1}{2}$ inches in diameter—$\frac{1}{2}$ inch for turning—a block $\frac{1}{2}$ inch in thickness is glued on the center of each half to form the

hub, and six annular segments 1¼ inches wide and ½ inch in thickness are glued around on the outer surface of each to form the rim and groove, as shown at *a* and *b*, Fig. 163. Care must be taken to place the segments so that the grain of the web will be crossed by two of the segments, as shown in the drawings. On the second half, *b*, of the pattern, a thin circular block ¼ inch in thickness is glued on the inside opposite to the hub block, to form the ⅛-inch projection which will keep the two halves of the pattern in alignment, as shown in the cross-sectional drawing in Fig. 160. Having glued up the stock as described, and as shown in Fig. 163, the outside must be planed to a level surface, or so that the six segments forming the rim and the center hub block will be in the same plane.

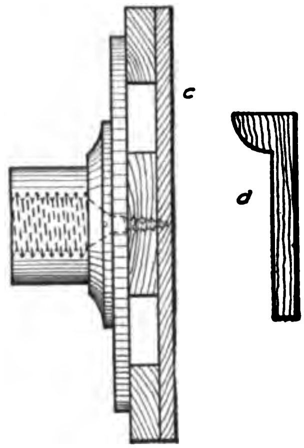


Fig. 164. Stock Mounted on Faceplate

The half pattern *a* is now screwed on the screw chuck of the lathe, as illustrated in Fig. 164, and the inside, or the parting face *c* is turned perfectly straight and true. The edge is turned down to 6 inches in diameter, and the quartered circle shown by the dotted lines in Fig. 159 is carefully shaped. A template, as at *d*, Fig. 164, will assist greatly at this stage of the work. A recess is turned at the center and in the face of *a*, Fig. 160, 1½ inches in diameter and ⅛ inch deep, to receive the corresponding projection on the half pattern *b* which is to keep the two halves in alignment.

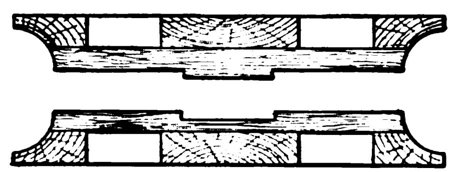


Fig. 165. Section Showing Joint of Sheave Pattern

The half pattern *a* is now removed from the screw chuck, and the second half *b* is screwed on and turned in the same manner except that the central projection is carefully turned to fit in the recess in *a*. Before removing *b* from the chuck, test by trying the second half *a*, and change *b* until a perfect fit is obtained between the two halves, not only in the central recess and projection, but also in the two curves which form the semicircular groove of the rim.

A cross-section of the pattern at this stage of construction is shown in Fig. 165.

A disk or chuck of wood 5½ inches in diameter is now screwed to the iron faceplate, or the screw chuck, and turned off true on the face, with a projection ⅛ inch high which will fit into the recess in the middle of the parting face of *a*. By this projection the half pattern *a* is centered on the faceplate, and can be held in position by two or four short wood screws driven through the web into the wooden chuck, as shown in Fig. 166. Care must be taken to place the screws in such a position that the screw holes will be cut or bored out when making the four or six openings 1 inch in diameter in the finished web of the pulley. The screws must be small and slender and the heads well countersunk out of reach of the turning tools. The face of the half pattern is now turned to the required shape, the template shown at *e*, Fig. 166, being used for the purpose. Having finished with fine sandpaper, remove the half pattern, and, turning off the projection on the center of the wooden chuck and making a recess instead to receive the projection on *b*, proceed with this second half as with the first.

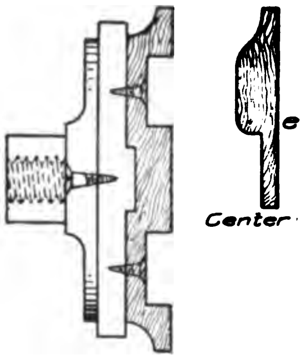


Fig. 166. Method of Mounting Sheave Pattern on Wood Faceplate

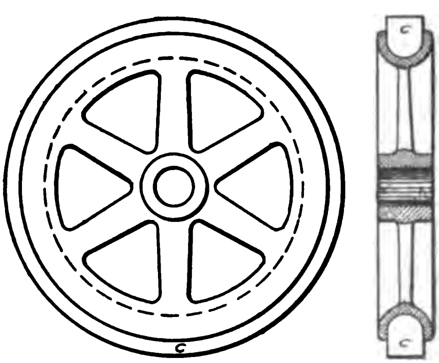


Fig. 167. Sheave Pulley Pattern with Groove Made with Dry-Sand Core

The 1-inch holes in the web are bored out with a 1-inch center bit, which, when well sharpened, does not split or splinter the thin webs of the two halves of the pattern if care is taken to reverse the bore from the opposite side when the point of the center bit comes through. The holes should be given a slight draft, as shown in Fig. 160.

If the wood has been well seasoned, and the work carefully done, a perfect 6-inch sheave-pulley pattern will be obtained. The pattern for a sheave pulley has been explained because it embraces so many profitable points and conditions, not only in gluing and

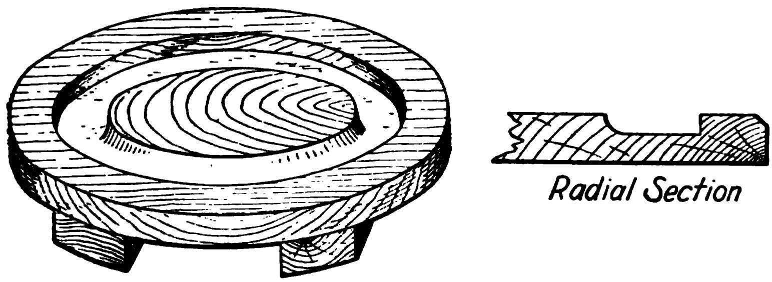


Fig. 168. Core Box for Sheave Pulley

building up, but especially in chucking and turning, all of which must be done with great care and accuracy.

Dry-Sand Ring Coring. A more practical way to produce castings of a sheave wheel would be to construct a solid wood pattern with a core print, as shown in Fig. 167, and to turn a half-core box, as shown in Fig. 168. In fact, this dry-sand-core method would result in greater economy in the foundry, as the saving in time required to mold the pattern would not be offset by the expense of making the dry-sand core.

When very large sheave pulleys having arms are to be made, such as are common for power transmission by rope or cable, the patterns are not halved but are made in one piece and the groove is cored around the rim, as illustrated in Fig. 167, with a wide core print *cc* extending entirely around the periphery of the pattern.

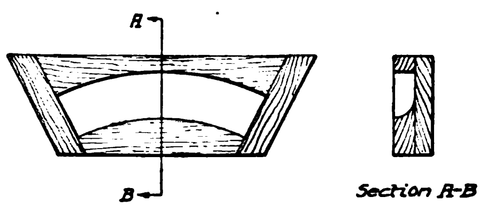


Fig. 169. Core Box for Single-Groove Rope Sheave

Segment Core. A segmental core box is made for one-sixth or one-eighth the circumference of the wheel, as shown in Fig. 169, and here again only half of the core box for a full core is needed. When coring the rim as above, the core print must be made deep, at least 2 to 3 times the depth of the groove, so that the core may rest firmly

and remain in position without tilting while the metal is being poured into the mold.

Hand Wheel

Conditions. The 12-inch hand wheel, Fig. 170, with five arms and a round rim finished to $1\frac{1}{2}$ inches in diameter, will also serve as a good illustration of pattern construction. On the rim of the pattern $\frac{1}{16}$ inch over all its surface must be allowed for finish, making the diameter of the rim of the pattern $1\frac{5}{8}$ inches and the outside diameter of the pattern $12\frac{1}{8}$ inches, while the inside diameter of the rim will be $8\frac{7}{8}$ inches.

To hold this work a wooden chuck—in this case a plain board $12\frac{3}{4}$ inches in diameter, and $\frac{7}{8}$ inch to $1\frac{1}{8}$ inches in thickness—is screwed to the iron face-plate of the lathe, and turned true on the face and on the edge to $12\frac{1}{8}$ inches in diameter.

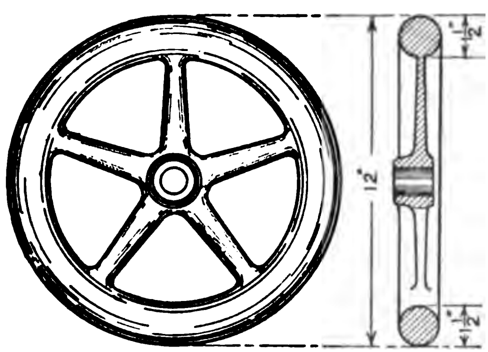


Fig. 170. Five-Arm Hand Wheel

Spider Pattern. The arms in this case should be made $\frac{5}{8}$ inch in thickness at the hub and $\frac{1}{2}$ inch in thickness where they enter the rim of the wheel. The construction is as shown in Fig. 171. Five pieces, each $6\frac{3}{4}$ inches long, $2\frac{1}{8}$ inches wide, and $\frac{5}{8}$ inch in thickness, are necessary.

Jointing Web. After being carefully fitted on the trimmer, a saw kerf $\frac{5}{16}$ inch deep is cut in each joint, *a*, Fig. 171, into which a thin tongue of wood is inserted and glued, the tongues serving as tenons to hold the arms together. After fitting, and before grooving with the saw kerf, the joints must be glue sized and, when dry, carefully scraped smooth with a sharp chisel. The grain of the wood in the tongues must run at right angles to or crosswise of the joint to insure the greatest strength.

Laying Out Arms. When glued together and dry, mark with dividers set to a radius of $6\frac{1}{4}$ inches, from the center or intersection of the five pieces, and cut off the ends of the arms so that they will project clear through the rim.

From the same center describe a circle 3⅛ inches in diameter, forming the web of the arms; and from this 3⅛-inch circle, taper the arms to ½ inch in thickness at the ends, care being taken to plane the same amount from each side, and to dress the arms evenly so that they will revolve in the same plane. This being done, from the center describe arcs on the outer ends of the arms, with a radius of 4⅜ inches (8¾ inches diameter, which is ⅛ inch less than the inside diameter of the rim), and divide the imaginary circle thus formed into five equal parts with the dividers. Draw radii from the points

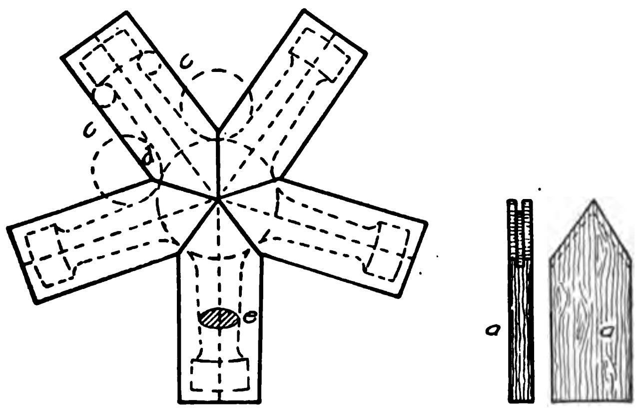


Fig. 171. Construction of Arm Pattern

thus obtained to the center. These radii will be the central lines of the arms, as shown by the dotted lines in Fig. 171.

On each side of the intersection of the radii and outer circle, measure ½ inch to the right and left, and on the circle denoting the circumference of the web, mark 11/16 on each side of the radii; connect the points thus obtained, and the result will be five arms 1⅜ inches wide at the web and 1 inch wide at the rim, as shown in the drawing. The ends of the arms which enter the rim should be, in this case, 1¾ inches wide, and the sides are drawn parallel to the radius which marks the center of each arm. The curves which connect the arms at the hub must be drawn of such radius as to make the curve tangent to the circle forming the extremity of the web, and also tangent to the sides of the two connected arms, as shown at *d*. The small circles at the intersections of the arms with the rim must be tangent

to the edge of the arm and to the 8¾-inch circle which marks $\frac{1}{16}$ inch less than the inside diameter of the rim, as shown at *cc*.

Having laid out the arms as above, and as outlined by the dotted lines in Fig. 171, saw them to shape and, before proceeding further with the arms, build the rim of the pattern on the faceplate.

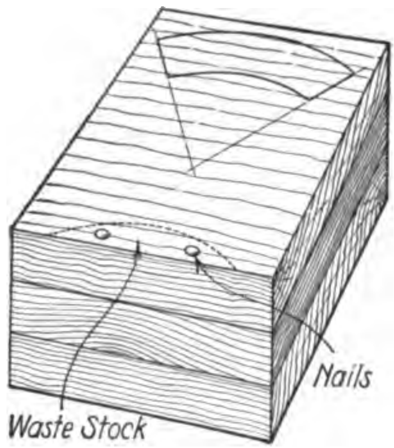


Fig. 172. Stock Prepared for Band-Sawing Segments

Building Rim. Prepare stock ½ inch thick, and saw to a length slightly greater than the chord for five segments. Stack and nail three of these pieces together, and lay out one segment, as shown in Fig. 172, as follows: outside diameter to be 12½ inches; width of segment 2 inches; and the chord equaling the diameter multiplied by the sine of half of the included angle, for example, the included angle being 72 degrees, the sine of 36 degrees equals .5877, and 12.5 times .5877 equals 7.35 inches, the length of the chord. Band saw these segments and use the top segment to lay out the other segments, marking them with a pencil. Glue a sheet of paper to the faceplate on the location of the rim of the pattern, and carefully fit and glue five of these segments to the paper, fastening the segments at the same time with two 1-inch finish nails. The heads of these nails should be driven below the surface of the stock. Be sure that the segments are concentric with the center of the faceplate.

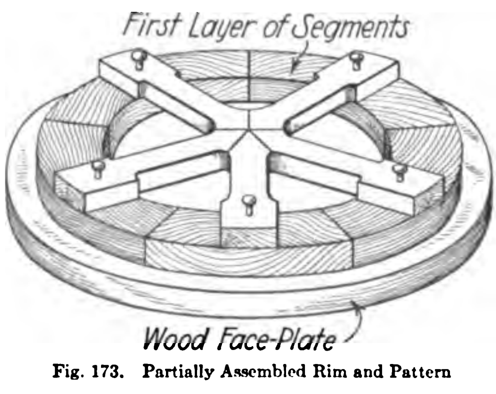


Fig. 173. Partially Assembled Rim and Pattern

As soon as the glue is dry, turn the face and the outer and inner edges of segments true. Locate the partially completed arms on this ring and fasten temporarily with five small nails, Fig. 173. Remove from the lathe, fit and glue the five segments between the ends of the arms, clamping these segments with two hand screws each while the glue is drying. Remove the arms as soon as the segments are glued in place, to prevent them from being glued in. As soon as the glue has set firmly, remove the hand screws and turn the inside edge of these last segments to their proper diameter and form, using a small sheet-metal template of zinc to test the form while turning. This turns the rim between the arms. Glue the arms in place, and also the last layers of rim segments, using the hand screws as before. The upper half of the rim can now be turned, using the template.

Before reversing, glue and nail five blocks of wood to the faceplate between the arms, pressing these firmly against the inner edge of the rim; these will serve to center the pattern afterward. The pattern can now be removed from the faceplate with a thin chisel and mallet. The paper will split and the nails will pull themselves either out of the pattern or the faceplate, and may be removed with a pair of pliers. Refasten the pattern on the faceplate by passing slim wood screws through the arms into the faceplate, or up through the faceplate into the rim. The five blocks glued to the faceplate will keep the work concentric. These screw holes can be filled with glued plugs when finishing the pattern.

Shaping Spokes. Trimming the arms to an elliptical form, as shown in the cross-section at Figs. 174 and 175, can be carried on while waiting for the glue in the rim to dry.

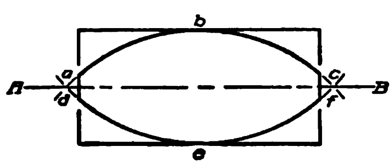


Fig. 174. Construction Lines for Section of Arm of Pulley

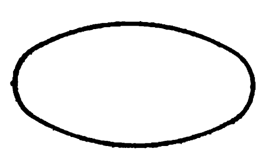


Fig. 175. Final Form of Arm between Rim and Hub

The finished shape of the arm, at any point in its length, is found by drawing a cross-section of the arm at that point, as in Fig. 174. Divide the cross-section equally by the line AB; measure out $\frac{1}{16}$ inch,

as at *a d* and *c f*, and with dividers adjusted so as to be tangent to the sides of the cross-section of the arm, and to pass through *a d* and *c f*, draw the curves *a b c* and *d e f*. After working off the sides of the arms to these curves, the angles at *a*, *c*, *d*, and *f* are carefully rounded with sandpaper, care being taken not to lessen the width of the arm at any point. The result will be as shown in Fig. 175, which gives a strong firm edge to the arm, and one which will not break or splinter off while being rammed up in the sand.

Forming Hubs. The hubs are to be turned from solid stock and with a draft or taper of $\frac{5}{8}$ inch in 12 inches, and must have a curve of $\frac{1}{4}$-inch radius at the base where they unite with the arms. If the hubs and the diameter of the cored hole are not liable to be changed, the nowel hub should be fastened firmly to the arms, and should be chucked into the arms, as shown in Fig. 176. This produces a fillet between hub and arms which is not liable to become loose. The fillets on both nowel and cope hubs should be turned on, and the cope hub should be made loose so that it will lift with the cope mold. If the pattern is to be completed as cheaply as possible, the hubs can be turned with a short 1-inch dowel, and fitted to a 1-inch hole at the center of the arms. In this case the fillet can be left off the cope hub, as a fillet this way is very fragile and easily broken. The molder will form the fillet in the green-sand mold. If the hubs are to be let into the arms, the recess in the arms can be chucked at the same time the rim is turned.

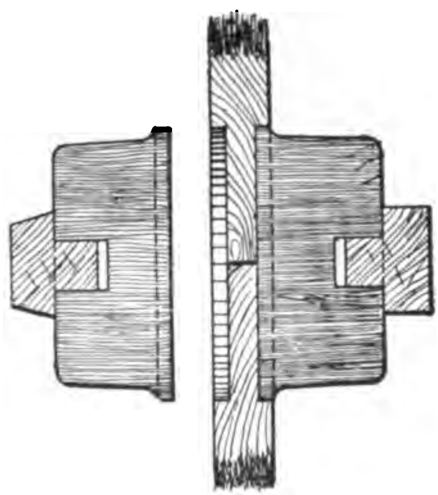


Fig. 176. Section through Center of Arm Hub and Core Prints. Nowel Hub Glued to Arms; Cope Hub Loose

After gluing on the hubs, smooth off all connected parts of rim, arms, and hub, and finish with three coats of shellac, sandpapering smooth between each coat as already described for other patterns.

Countershaft Pulley

Construction for Special Size. The making of patterns for special pulleys enters largely into the work of many pattern shops. In these patterns the rims are built up of segments $\frac{3}{8}$ inch to $\frac{1}{2}$ inch in thickness. To illustrate this work fully, let us take up the successive steps in the construction of a countershaft pulley 20 inches in diameter and of 6-inch face, made to fit a shaft $1\frac{3}{4}$ inches in diameter. The pattern for such a pulley is shown in Fig. 177.

Allowances in Dimensions. The diameter of the web of the arms is 5 inches, and the diameter of the hub $3\frac{1}{2}$ inches at each end and tapering up to $3\frac{3}{4}$ inches in diameter at the arms.

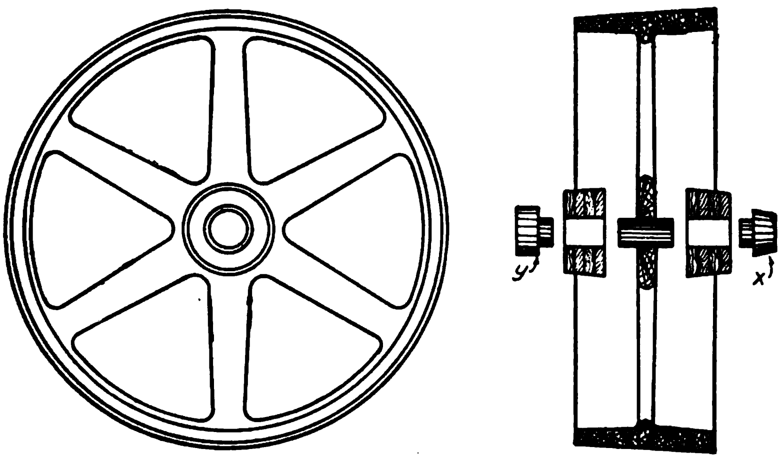


Fig. 177. Sectional View of Pattern for 20-Inch Pulley

If the rim is to be finished on the face and edges only, $\frac{1}{16}$ inch must be allowed for facing, making the outside diameter of the pattern $20\frac{1}{8}$ inches; and the width of the face should be $6\frac{1}{2}$ inches. In addition to $\frac{1}{16}$ inch for finish, the draft on the outside of the rim, from each edge to the center, should be in the ratio of $\frac{1}{8}$ inch to 12 inches, and on the inside of the rim the draft must be $\frac{1}{4}$ inch in 12 inches. The thickness of the rim at its thinnest edge is $\frac{1}{4}$ inch and, with outside and inside draft added, its thickness at the arms will be about $\frac{3}{8}$ inch. The inside diameter of the rim at the arms will be $19\frac{3}{8}$ inches.

Arms. This pulley should have six straight arms $\frac{3}{4}$ inch in thickness at the hub and $\frac{5}{8}$ inch in thickness at the rim. The width of

the arms at the web should be 1¾ inches and at the rim 1½ inches, exclusive of the connecting curves at web and rim.

Jointing. Six pieces 10½ inches long, 2¾ inches wide, and ¾ inch in thickness, must be carefully fitted, as shown in Fig. 178. After fitting, the connecting joints are glue sized, and, when dry, carefully scraped smooth with a sharp chisel, and a saw kerf $\frac{5}{16}$ inch deep cut in each. The tongues used for tenons in these kerfs should be a little less than ⅝ inch long, the grain of the wood running always at right angles to the line of the joint to give the greatest strength to the tenons.

The six pieces should be glued in two groups of three pieces each; and, when dry, these two groups can easily be refitted, if necessary, and glued.

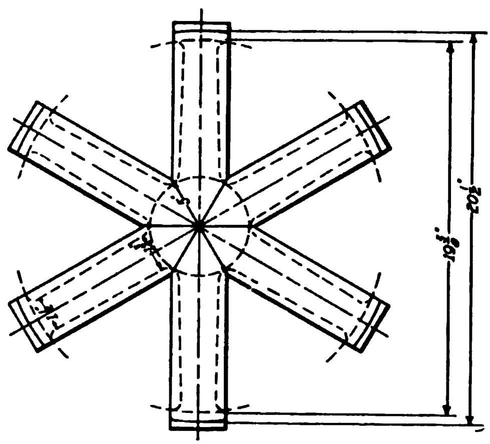


Fig. 178. Layout of Arms for Fig. 177

Laying Out. The next step is to draw, from the center formed by the intersection of the six pieces, a circle 5 inches in diameter, representing the web of the arms, and, near the extremities of the pieces, the arcs of a circle 20½ inches in diameter, representing $\frac{5}{16}$ inch greater diameter than the outside diameter of the rim at the location of the arms. Carefully divide these last arcs into 6 equal spaces with the dividers, bringing the points thus obtained as nearly to the middle of the six arms as possible; and from the six points thus spaced, draw radial lines connecting them with the center or intersection of the six arms. These radial lines, shown dotted in Fig. 178, are the center lines of each arm.

Saw off the ends of the arms on the above 20½-inch arcs, and from the center again draw on the six arm pieces a third circle, whose diameter should be at least ⅛ inch less than the inside diameter of the rim—in this case 19 inches. On these arcs measure ¾ inch on each side of the center line, and on the circle representing

the web measure $\frac{7}{8}$ inch on each side; connect these points from web to rim, and the arms will be $1\frac{3}{4}$ inches wide at web, and $1\frac{1}{2}$ inches at the rim.

These lines are shown by the dotted lines in Fig. 178. The width of the ends of the arms passing through the rim should be about $2\frac{1}{2}$ inches, and the sides of the end sections should be drawn parallel with the center line of the arm, as shown for the hand-wheel arms in Fig. 171. The radius of the circle connecting the sides of the arms and the web must be such as to be tangent to the edges of the two connected arms, and also tangent to the circle marking the diameter of the web.

The smaller curve connecting the two edges of each arm with the rim must be of such radius as to be tangent to the arm and to the $19\frac{3}{8}$-inch arcs which mark the inside of the rim in the plane of the arms. All these lines are shown dotted in Fig. 178.

Shaping. The arms are now ready for sawing to shape on the band or scroll saw, care being taken to saw just outside of the lines so that each arm may retain its full size and width. After sawing to shape, the edges must be dressed smooth and free from all irregularities of the sawing.

Next, from the web circle, taper the arms to $\frac{5}{8}$ inch in thickness at the extreme ends, care being taken to see that the taper of both sides of the arms is uniform from the web circle to the rim.

The shape of the arms should be elliptical or nearly so, and a cross-section at any point in an arm may be obtained in the same manner as described for the hand wheel shown in Figs. 174 and 175, and the methods used for shaping and finishing are the same.

Rim Construction. *Use of Chuck.* For building the rim, a wooden chuck $20\frac{1}{2}$ inches in diameter will be necessary. A board $\frac{7}{8}$ inch in thickness and having a bar 8 inches wide and of the same thickness, well screwed to the back with wood screws, is all that is necessary for a pulley of this size. To the 8-inch bar, the iron faceplate of the lathe is screwed, and the whole turned off true in the lathe, especially the face of the chuck to which the first layer of segments is to be glued.

Strips of paper will be glued between the first layer of segments and the face of the faceplate so that the completed rim may be

easily removed—repeating the process used for similar work in making the 12-inch hand wheel.

Process. Prepare stock $\frac{5}{8}$ inch thick for rim segments, cutting the stock long enough to make 6 segments for each layer, and 11 layers, making 66 segments. Stack the stock and band saw at least 4 segments at one time. Have the layout and process carried out the same as suggested for the 12-inch hand wheel.

The segments should have an outside diameter of $20\frac{1}{2}$ inches, and inside diameter of 19 inches, making a width of $\frac{3}{4}$ inch, and a length $\frac{1}{16}$ inch longer than the outside radius. The grain of the stock should be parallel to the chord of the segment.

The first layer is fitted and glued to the faceplate with paper between, and securely clamped with small hand screws through to each segment. Do not use any nail this time, as the rim is only $\frac{5}{16}$ inch thick at the edge next to the faceplate. When the glue is dry—one hour being sufficient—place the faceplate in the lathe and carefully turn off the face of the segments true, and also turn the inside edge of the segments to the proper diameter and draft.

Before turning the face of the second layer of segments, glue to the faceplate—six pieces of stock $\frac{1}{4}$-inch thick—using no paper—so that they will bear firmly against the inner edge of the segments in the first layer, to prevent the work from becoming loose. Do not glue these blocks to the rim segments. No nails should be used in any work of this description. Fit and glue the second layer, and when the glue is sufficiently dry, turn the face and also the inside edge as before. Do not turn the outside edge of the segments at this time, but it is best to mark an oversize diameter with a pencil or the point of a chisel to keep the layers concentric. This layer, in turn, is turned off in the lathe, and the third layer is glued on, hand screws being used on each layer as on the first, and the joints of the segments so broken that no two will be directly opposite each other, all joints being carried to right or left of all preceding joints, thus securing the greatest possible strength to the rim.

Having glued on a sufficient number of layers to build the rim up to the edge of the arms—five in this case—fasten the arms temporarily in their correct location, and glue the segments between the ends of the arms. Remove the arms—as noted while considering the 12-inch hand wheel—and turn out the inside of the rim

to the finished diameter and draft, and smooth with sandpaper. Glue the arms back into place, first seeing that the fillets which have been used at the outer end of the arms are trimmed to fit the the inside of the rim.

The next five layers of the rim are built on the same way, except that the inside edges need not be turned until all layers are in place. The outside of the rim should be turned straight, with its largest diameter next to the faceplate. This diameter should be $20\frac{1}{4}$ inches, and, as the outer edge of the rim is to be made $20\frac{1}{8}$ inches in diameter to allow facing, this gives $\frac{1}{16}$ inch for draft.

The parting of the mold should be flush with one edge of the rim, and coped down to the center of the arms on the inside of the rim. This allows more than the usual amount of metal finish on one edge of the rim, but, if the face of the rim were crowned or drafted both ways from the center of the arms, a perfect lift would be difficult when the cope mold is lifted to get at the pattern.

Use of Loose Hub. To permit a satisfactory lift, the cope hub should be made loose so that it will lift with the cope mold. In constructing any pattern it is best to so arrange its parts that change may be made in order to adapt the pattern to as many requirements as possible. Even if this pulley is designed as a standard part of some equipment, there are times when it might be used for other purposes that would likely require a larger shaft, a longer, or an offset hub. To meet these conditions, make all hubs and core prints loose.

The pulley being intended for a $1\frac{3}{4}$-inch shaft, the core prints x and y, Fig. 177, should be $1\frac{1}{2}$ inches in diameter, which will give $\frac{1}{8}$ inch of metal for boring out to fit the shaft. The hubs should be turned from solid stock, having the grain run parallel to the length of the hub. Select stock 4 inches by 4 inches and saw two pieces $2\frac{1}{2}$ inches long. Band saw to a circle $3\frac{3}{4}$ inches in diameter and bore a 1-inch hole through each at the center. Mount these pieces on an arbor; turn to a diameter of $3\frac{1}{2}$ inches at one end, and a draft of about $\frac{1}{4}$ inch per foot should be allowed on the outside diameter. The length of the hubs should be $2\frac{1}{4}$ inches each.

Fillet. No fillet should be turned on the large end of the hubs, as it is easily broken and it will be easier to lengthen the hub by the addition of a thin piece of stock, should occasion demand, if the

hub is made straight. The molder can produce the fillet by slicking the corner of the mold with a fillet tool.

Core Prints. Core-print usage is discussed in the next section, in the paragraph on "Standard Core Prints".

Standard Pulleys

Method of Construction. It is the same with the pulley pattern as with most other patterns—the number of castings required and the complexity of the demands determine the method of molding. Several methods of molding a pulley, and the dependent pattern, are considered.

Variable Iron Rim. When pulleys of standard sizes for line shafting are manufactured in quantities, a skeleton pattern consisting of hub, arms, and an independent iron rim is used. This iron rim is of moderate width but may be used for obtaining any width of face desired.

Rim Master Pattern. *Shrinkage Allowance.* Where a wood pattern for the iron rim is to be made, the same care is necessary in the building up of the original wooden pattern. It must be remembered that before the final casting is obtained, two shrinkages will take place; first, the shrinkage of the original casting from which the iron ring is turned, and then the shrinkage of the casting made from this pattern. In addition to this, there must be the allowance for turning the ring both inside and out and for the turning of the outside pulley rim.

Suppose the pattern is to be made for a pulley 2 feet in diameter. The usual allowance for a single shrinkage is made by the shrinkage rule. In this case the allowance must be doubled. Thus, in the above pulley, the diameter of the wooden pattern becomes $24\frac{1}{4}+\frac{1}{4}=24\frac{1}{2}$ inches, standard-rule measurements, or $24+\frac{1}{4}=24\frac{1}{4}$ inches, shrinkage-rule measurements. As a very smooth surface free from holes is required, $\frac{1}{4}$ inch in diameter, or $\frac{1}{8}$ inch all around must be allowed for outside finish on the iron ring, and $\frac{1}{8}$ inch for finish on the rim of the cast-iron pulley.

The outside diameter of the original wooden pattern is $24\frac{1}{4}+\frac{1}{4}+\frac{1}{8}=24\frac{5}{8}$ inches, with shrinkage rule. If the final thickness of the pulley rim is to be $\frac{3}{8}$ inch, this, with the allowance of $\frac{1}{8}$ inch for turning out the inside of the iron ring, makes the inside diam-

eter of the wooden pattern 23 inches, and the thickness of the wooden rim $\frac{13}{16}$ inch, all shrinkage-rule measurements.

Construction. This wooden-rim pattern must be built up on a chuck, as described for the 20-inch by 6-inch pulley, the segments, six in number for each layer, fitted, glued, and clamped with three hand screws to each segment until a width of $6\frac{1}{2}$ inches is reached.

It is then turned to the above dimensions, without any draft, and sent to the foundry, where it may be used for obtaining an iron rim of any required width by first ramming the sand about the pattern, partly drawing it, and then ramming again to a new level.

At least four pieces of stock about 3 inches long by 2 inches wide and $\frac{5}{8}$ inch thick should be furnished the molder to bed in on the outside of the wooden-rim pattern at the mold parting, to permit casting lugs on the rim for clamping the casting to the faceplate while it is being finished to final dimensions, the casting being made wide enough to cut these lugs off when the lathe work is completed.

The casting thus obtained is then turned to the dimensions called for by an ordinary pattern; that is to say, the shrinkage-rule measurements would leave it $23\frac{1}{4}$ inches in diameter on the inside and $24\frac{1}{8}$ inches on the outside, permitting a final finishing of the outside of the rim of the pulley to a diameter of 24 inches. When this is done, two $\frac{3}{8}$-inch holes should be drilled near one edge of the rim and diametrically opposite each other, into which hooks may be inserted for drawing the pattern. This rim should also be turned straight and without any draft.

Arms. The arms are usually made with a wooden pattern, which has a dowel-pin hole on each side at the center for attaching the hubs that are loose, the object being to change their length and diameter to suit the width of the rim and the diameter of the shaft upon which the pulley is likely to be placed.

Shape. The arms of all pulleys should be straight, because of the greater strength given to the pulley as a whole, the driving and resisting power being at least one-third greater than in a pulley of the same dimensions having curved arms. Curved and shaped arms of all kinds are now used only for ornamental purposes and for very light work.

Size. The arms should be six in number, except for very small pulleys, when five, and even four, are often used. The dimensions

of the arms vary greatly, depending on the purpose for which the pulley is to be used, and the weight of the machinery to be driven. For the beginner, the following formula is safe to follow:

$$b=\sqrt[3]{\frac{d\times w}{n\times 8}}$$

in which—all dimensions being taken in inches—

b = the breadth of the arm at the outer end
d = the outside diameter of the pulley
w = the width of the rim
n = the number of arms

Thus, for a pulley 24 inches in diameter, with a rim 6 inches wide and fitted with 5 arms, the formula becomes

$$b=\sqrt[3]{\frac{24\times 6}{.5\times 8}}=\sqrt[3]{3.6}$$
$$=1.53 \text{ inches, or say } 1\tfrac{1}{2} \text{ inches}$$

The width of the arm should be one-fourth greater at the hub than at the rim. The thickness at the hub and rim should be one-half the width, and the section should be elliptical. The arm just calculated then becomes

$1\frac{1}{2}$ inches wide at rim
$\frac{3}{4}$ inch thick at rim
$1\frac{7}{8}$ inches wide at hub
1 inch thick at hub

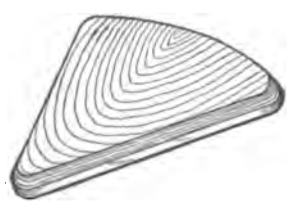


Fig. 179. Pattern for Lifting Plate

Fig. 180. Lifting Plate Arm

As a rule, all of the dimensions of the pulley should be furnished the pattern maker by the designer.

Lifting Plate. *Use.* In molding patterns made as above, the molder will require a lifting plate. The lifting plate is anchored to the top of the cope block and will lift the center of the mold without any liability of its dropping.

Pattern. The patterns for this lifting plate can be made as follows: From a piece of stock $\frac{3}{4}$ inch thick, band saw six

pieces, as shown in Fig. 179, making them about $\frac{3}{4}$ inch smaller all around than the space between the two adjoining arms and the inside of the rim. Chamfer one edge all around so as to leave the vertical edge about $\frac{1}{4}$ inch thick. Band saw six pieces from $1\frac{3}{8}$-inch stock

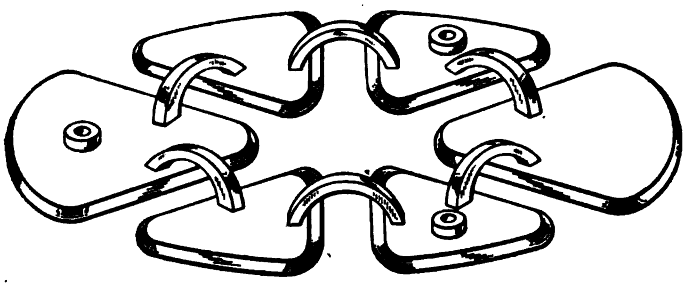


Fig. 181. Assembled Lifting Plate for Six-Arm Pulley

to the proportions shown in Fig. 180, and reduce the thickness at one end so as to form a draft. These pieces are drawn from the mold endwise, and the casting appears as shown in Fig. 181. Three circular pieces of stock $1\frac{1}{2}$ inches in diameter by 1 inch thick are furnished to form bosses, which are tapped for a $\frac{5}{8}$-inch or $\frac{3}{4}$-inch rod.

Hubs. An ordinary rule is to make the outside diameter of the hub twice the diameter of the shaft. The two half hubs—one on each side of the arms—are usually loose and are held central by a single dowel pin. Their diameters are adapted to the size of the shaft upon which the pulley is to run, and the length is proportioned to the width of the rim as well as its diameter. The length of the hub should be about two-thirds the width of the rim, except in the cases of tight and loose pulleys, where the hub should be a trifle longer than the width of the rim, and it may then project about $\frac{1}{8}$ inch on the sides in contact, and $\frac{1}{4}$ inch on the outside.

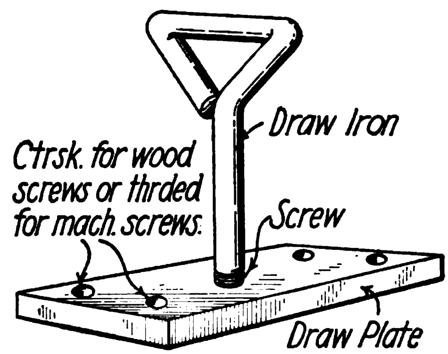


Fig. 182. Rapping and Draw Plate

Rapping Plate. *Use.* When a pattern is imbedded in the sand, the latter is closely compressed all about it, and slightly adheres.

The molder is therefore in the habit of rapping the pattern gently in order to loosen it in the sand before attempting to draw it. If the pattern is not provided with a metal plate, the molder will drive the sharp point of a lifter into the wood and strike it alternately on opposite sides and at the same time use it to lift the pattern from the sand. This mars the pattern and will in time ruin it.

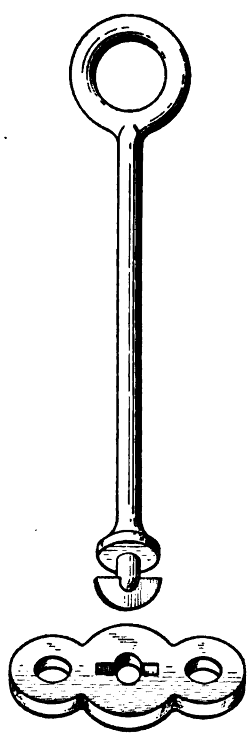


Fig. 183. Key Draw Plate

The rapping plate shown in Fig. 182 is a piece of thin metal $\frac{1}{8}$ to $\frac{3}{16}$ inch thick, inserted so that it is flush with the parting face of the pattern and is held by wood screws with countersunk heads. These plates are drilled and tapped for a $\frac{3}{8}$-inch screw and should be the same for all patterns in the foundry so that one set of rods can be used interchangeably. The method of using is to screw the rod into the plate and rap it gently to and fro until the pattern has been loosened, when it may be lifted.

The Acme key rapping plates, Fig. 183, are quickly attached to the pattern, the mortise being bored out with a bit.

Placing. For small patterns, one rapping plate will be sufficient and this should be so placed that the hole for the lifting rod comes directly over the center of gravity of the piece. This prevents tilting of the pattern as it is lifted from the sand. However, if there is a portion of the pattern away to one side of the center of gravity, which by its nature is liable to resist drawing more than the other side, the rapping plate should be located away from the center of gravity toward this side of the pattern so that in drawing the lift will be nearly over the resultant center of resistance. For medium-sized patterns, two rapping plates should be provided so that the pattern can be raised from two opposite sides. For still larger patterns three or four rapping plates are used, the object being to give such perfect control when drawing that there can be no tearing away of the sand.

Standard Core Prints. *Economy in Use.* While standard dimensions of the cylindrical core prints are not universally used, many large corporations operating pattern shops and foundries have adopted a standard, and the economy of this practice should recommend it to all. Most foundries will keep on hand cylindrical dry-sand cores, whether the cores are made in wood or in metal core boxes or with the core machine.

The value of the fixed taper and length to the cope core print is most apparent. This form can then be made at one end of the core box, and the machine-made cores can be ground to a fixed angle by having a guide table fitted to the emery-wheel stand. A foundry equipped in this manner can always fit a pair of prints to the pattern and be sure that the cope end of the vertically set cores will

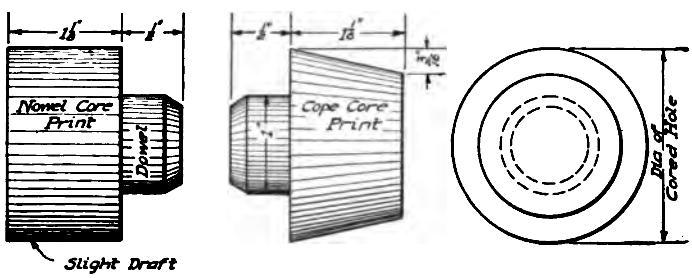


Fig. 184. Proportions of Standard Core Print

fit the print mold. It will also save the pattern maker the expense of turning a pair of prints every time their use is required. A pattern shop, having a dozen pattern makers employed, will get a dozen different forms to the cylindrical core prints if no standard is followed, and much time will be used in the foundry filing cores to fit.

Stock Sizes. If you know where the pattern is to be sent, better find out if the foundry has a standard for their stock cylindrical cores, and build your core prints to conform to it.

There need be no standard length for the prints of a horizontally set core, for in this case the print should be long enough to give a seating sufficient to hold the core from either settling or rising. The upward strain of a core during pouring will be greater than the downward strain due to its own weight.

Dry-sand cores are usually kept in stock from 1-inch up, by eighths, viz, 1-inch, $1\frac{1}{8}$-inch, $1\frac{1}{4}$-inch, etc. All core prints used on

patterns considered here will use prints dimensioned according to Fig. 184, unless they require a change in size due to extreme length and weight of the core, or to some special process of molding.

Large Cored Pulley

Molding Method. For the larger sizes of cast pulleys, including spur gears, rope sheaves, and balance pulleys, the wooden-arm and metal-rim patterns are impractical. In Fig. 185 are shown the dimensions of a single six-arm solid pulley which is molded by means of dry-sand cores and sweeping. The patterns for the double-arm,

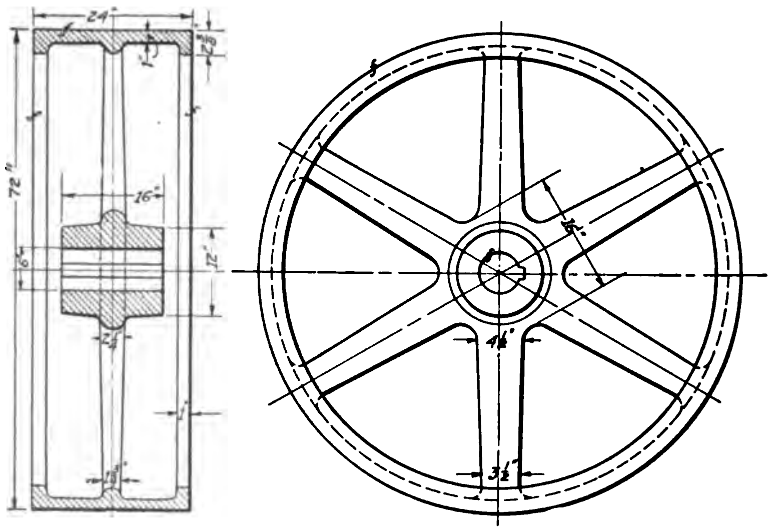


Fig. 185. Dimensions of Cored-Arm Pulley

clamped between the arms, and clamped through the arms, are adaptations of the same process.

Arm Core. First prepare an arm core box, Fig. 186, which shows the core box with the near side removed so as to exhibit the hub and arm pattern in place. This box should be made of 1½-inch stock, and 3½ inches deep by 10 inches wide inside; one end will be fitted to form a 60-degree angle, while the other end will be left open. Make the inside length about 48 inches, as this core box can be used for larger diameter pulleys. Have the core box well screwed together, cleated on the bottom, finished smooth, and shellacked on the inside.

Fig. 187 shows a section through the center of hub *a*, arm *b*, and inside rim pattern *c*, these three parts being made separate, so that by slight alterations they can be used for other diameters. The hub *a* is made of three pieces of stock, the lower being the

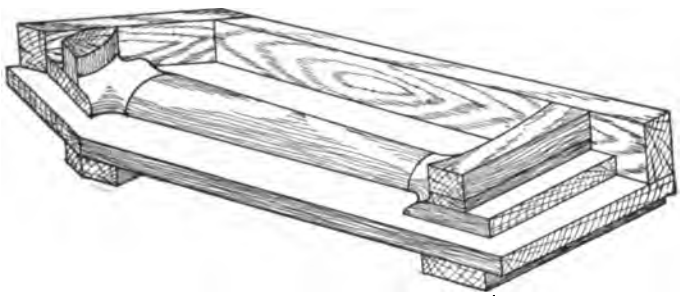


Fig. 186. Core Box for Arm

thickness of one-half of the arm. The grain of this stock should be parallel to the length of the core box. Lay out from the center line the 60-degree angle and form of the arm at the center of the pulley, as shown in Fig. 187. The next two pieces of stock, a' and a'', should have the grain at right angles to the length of the core box; the thickness of a' to be $\frac{5}{8}$ inch, out of which is carved the fillet. These two pieces are to be fitted into the core box, and the arcs from the outside of the hub scribed from the center on the core box. The outside of a'' may be smoothed with a spokeshave and sand-paper before the three pieces are nailed—not glued—together, but

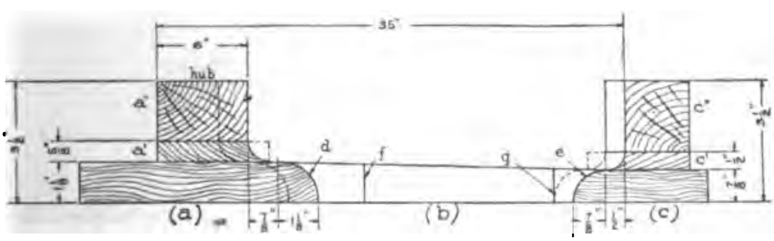


Fig. 187. Construction Diagram for Arm Pattern

the fillet on a' had best be carved after the assembly. Trim section *a* at *d* to make the round beading between the arms, and trim *a* at *f* to a half ellipse.

The rim end of the arm pattern *c* and its parts c' and c'' are constructed by the same process, fitting the pieces of stock into the

core box and scribing the arcs for the inside of c' and c''. The inside of c'' should be finished smooth, using a spokeshave or a circular plane, as described in Part I. Carve the fillet on c' after assembling.

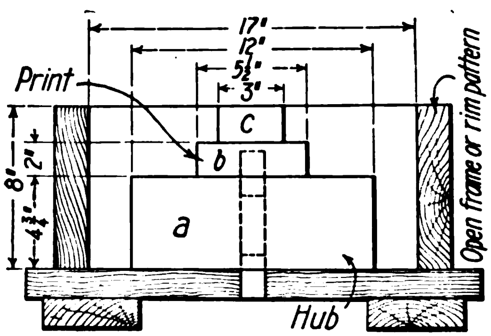


Fig. 188. Section of Hub Core Box

The arm b is planed to the required form of half the arm. These three parts are shellacked in the same manner as described before, and are fastened into the core box with wood screws. Be sure that the arm is central in the core box.

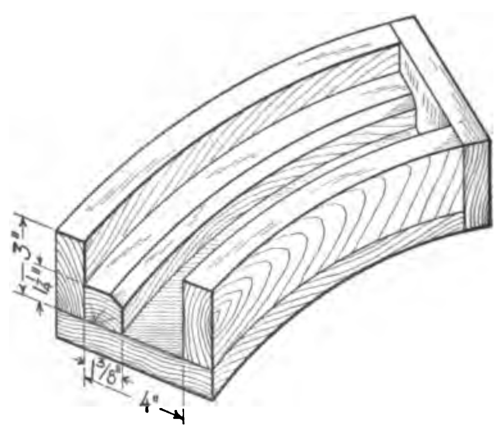


Fig. 189. Inside Flange Core Box

Hub-End Core. The pattern for the ends of the hub receive our next consideration. The arm core box was made 3½ inches deep, so there remain 4¾ inches of hub outside the arm core box on each side, allowing ¼ inch for metal finish on the ends of the hub, as indicated in Fig. 188.

Glue 1½-inch stock together, to make the hub 12½ inches in diameter by 5 inches long. Plane one end true, bore a 1-inch hole at the center, and, after band sawing to a rough diameter, fasten to a faceplate having a 1-inch pin at its center. Turn to the required diameter and length, allowing a slight draft to the outside. Bore a 1-inch hole at the center. If the hub is not too large, it should be turned on an arbor, and also if quite large the hub may be con-

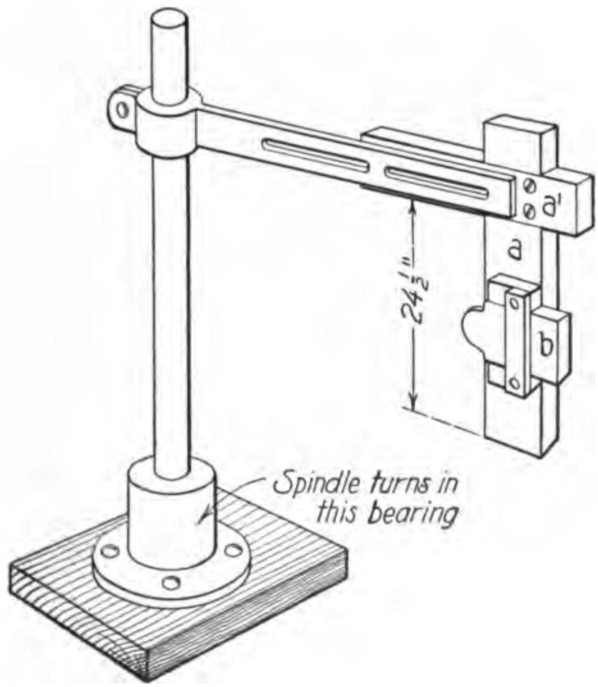


Fig. 190. Centering Spindle and Rim Strike

structed of two circular heads, nailing and gluing narrow stock—lagging—to the periphery of these heads or ends, and turning the hub after the glue is dry, as noted above.

The core prints in this case can be made of flat stock fitting a 1-inch pin at center, and nowel *b* and cope core prints should be about 2 inches thick. An addition *c* to the core prints, 3 inches in diameter and about 1½ inches thick, should be fastened and turned with them. The upper end of this 3-inch piece shall be flush with the frame, forming the outside of the core. If the foundry is equipped with

iron pulley-rim patterns, one of these can be used, striking down to the top of the 3-inch print *c* if the edge of the rim pattern is too high.

Flange Core. The length of the core box for the inside flange, Fig. 189, will be made to allow twelve half cores. Multiply the inside diameter of the rim, 70 inches, by the sine of half of the included angle, .2588, which will equal 18.11 inches for the longest length of the inside of the core box. The thickness of the stock used for the

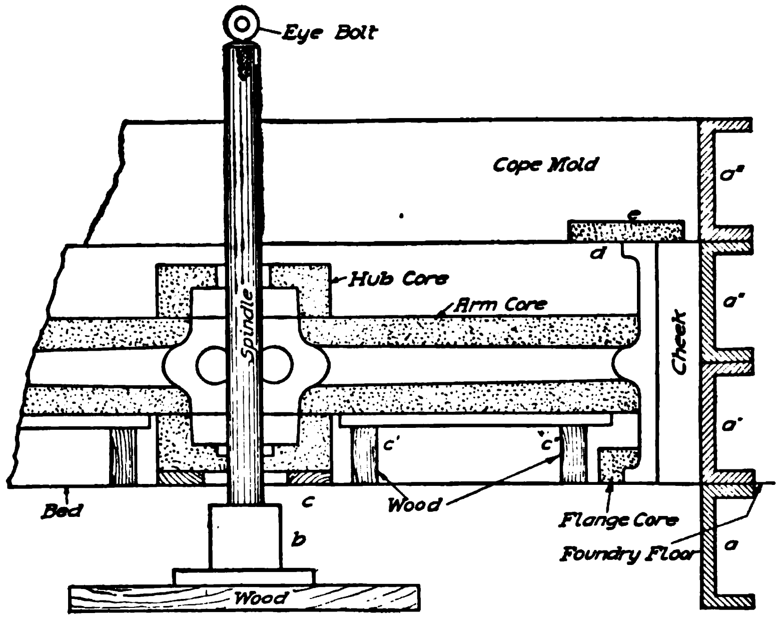


Fig. 191. Section of Cored-Arm Pulley Mold

core box should be about $\frac{7}{8}$ inch, and the other dimensions are given in Fig. 189.

Two patterns for the flange will be made, one to be nailed in place in the core box, and one to be used to mold the upper inside flange.

Strike. The strike *a*, Fig. 190, is made of two pieces of stock $1\frac{1}{8}$ inches thick by 5 inches wide, halved together. The finger board *b* strikes the beading between the arms, and the inner end is sawed to the sectional form shown in Fig. 187. The length of strike *a* will be $24\frac{1}{2}$ inches long, allowing for $\frac{1}{4}$ inch for metal finish on each edge of the pulley face.

Molding Process. A brief description of the molding process will make the use of this equipment clear.

Twelve half cores are made in the arm box, Fig. 186, and pasted together to make six dry-sand arm cores.

In the hub box shown in Fig. 188 one core is made for the lower end of the hub mold, and one core with the core print *b* cut through to the top of the core to clear the sweep spindle. Twelve cores are made in the flange core box.

A cheek flask is bedded in the ground *a* and the standard with spindle is also bedded in, as shown at *b* in Fig. 191. The bed is struck off and the flange cores set concentric with the spindle. Block up under the lower hub core at *c* and under the arm cores at c' and c'' to locate the arms at the center of the face. A brick wall is loosely laid up just outside the lower flange cores, to the height of face required. The center is then filled with green sand and rammed hard, the upper hub core being placed over the spindle. The brick wall is now torn down and the strike set in position, striking off the green sand, to the end of the arm cores.

The cheek flask being put into position $a'a''$, the mold is rammed in green sand outside of the lagging which is placed next to the inside mold to give the thickness to the rim. The cheek is removed and slicked. The upper flange is bedded in at *d;* the spindle is withdrawn and replaced with the shaft-hole core; the cheek is replaced; flat covering cores are placed over the rim mold *e;* and the cope is rammed. The gates, sprues, risers, and pouring basins will not require any pattern labor.

Some molders prefer to make the outside of the rim with dry-sand cores, and this is always the method employed for rope sheaves.

FLAT-BACK PATTERNS

Solid Engine Crank

Construction. The heavy engine-crank pattern illustrated by Fig. 192 should be built of five layers of stock, gluing heart sides and bark sides of each piece together, as shown in Fig. 193. Dress the stock true on one side and edge for a working face and a working edge. Machine-plane the opposite side and edge parallel to these faces. Lay out the plan of the crank on one face and also a side elevation on one side of the stock. Square around the stock for the

location of the holes—15-inch centers—and bore 1-inch holes on both sides of the stock at these centers. Carefully band saw to line

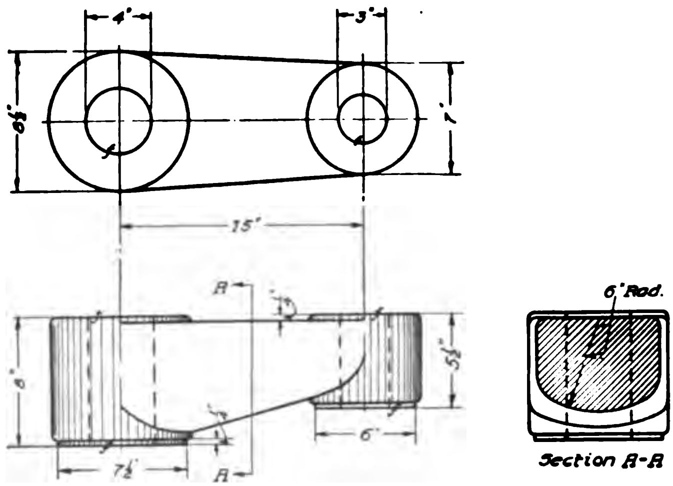


Fig. 192. Detail Drawings for Heavy Engine Crank

a, Fig. 193, and leave stock at *b* so as to keep the top of the stock parallel to the band-saw table when sawing the line *c*. This stock *b* may be removed with a chisel after all band-saw work is completed. Have the band-saw table tilted when sawing to line *c* so as to produce a slight draft—⅛ inch in 12 inches—to the sides of the pattern.

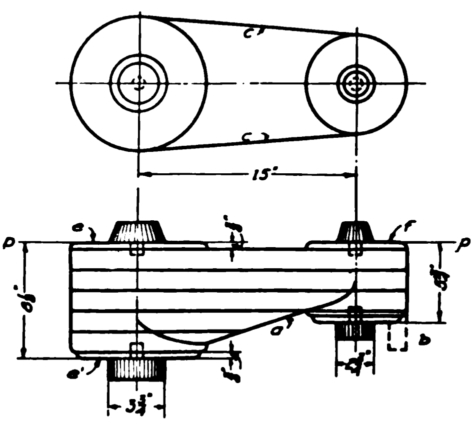


Fig. 193. Diagram of Pattern for Crank, Fig. 192

Turn a nowel and cope core print 3¾ inches and also 2¾ inches in diameter, according to the standard adopted for core prints. The bosses *e* and *f* are to be made of flat stock ⅜ inch thick. Prepare a wood faceplate with a 1-inch pin at its center. Having a 1-inch hole at the center of

the boss, fasten the bosses to the faceplate with four $\frac{3}{4}$-inch wire nails; now turn them to the diameters required by the drawing and bevel the edge about 30 degrees. Nail and glue on the bosses, being sure the holes are in line with the holes in the body of the pattern.

The sectional view in Fig. 192 shows the form of the crank at mid-length, and the pattern should be finished to this form, using a template to test the accuracy of the round corners. The dowels of the nowel core print should fit tightly, but are not to be glued to the pattern unless it is known that the size of the cored hole will not be altered. The cope core prints should fit loosely, so that they can be removed while ramming the nowel mold. The mold parting will then occur on line *pp*, Fig. 193, and the parting will be coped down to the round corners. Patterns like Fig. 193 and Fig. 195 are known as flat backed; no part of the pattern except the cope core prints extends into the cope mold.

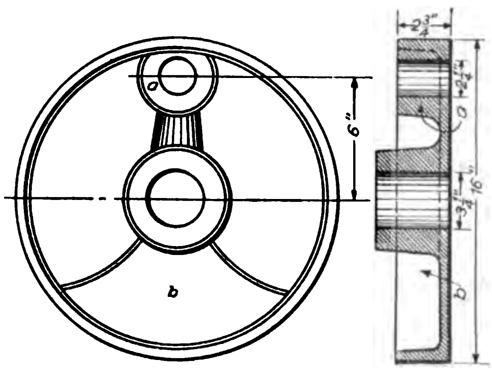


Fig. 194. Disk Crank

Disk Crank

Construction. Fig. 194 illustrates a finished cast-iron disk crank for an engine of 12-inch stroke. This crank is finished on the face, on the outer edge, and on the end of the hub. It is bored out $3\frac{1}{2}$ inches to fit on the engine shaft, and $2\frac{1}{4}$ inches to receive the wrist pin. An addition of $\frac{1}{8}$ inch must be allowed on the pattern for finish of the face, and the same on the end of the hub; $\frac{3}{16}$ inch will be sufficient to add for finish on the outer rim, making the diameter of the pattern $16\frac{3}{8}$ inches, and the thickness of the disk $\frac{3}{4}$ inch. A sectional view of the pattern is shown in Fig. 195.

Disk. The disk or web for this pattern is to be made of six sectors, Fig. 196. The finished thickness of the web will be $\frac{5}{8}$ inch, and, allowing $\frac{1}{8}$ inch for metal finish, the web of the pattern will be $\frac{3}{4}$ inch thick. Each section after being fitted should have the edges

glue sized, and be grooved for a spline. The grain of the stock used in these splines should be at right angles to the joint, as mentioned in the consideration of the hand-wheel pattern, Fig. 171. Band saw this web to a diameter $\frac{1}{4}$ inch greater than required for the completed pattern, bore a 1-inch hole through the web at the center, and fasten to a wood faceplate having a 1-inch pin at its center, with six $1\frac{1}{2}$-inch wood screws, as shown in Fig. 196. Turn the rabbet in the web at d and chuck the center at e, as shown in Fig. 195.

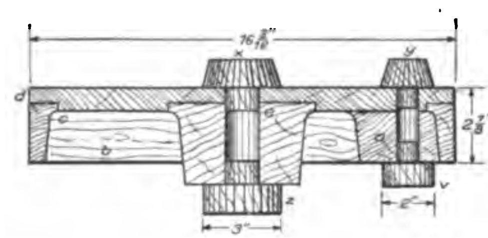


Fig. 195. Section of Pattern for Disk Crank

Rim. The first layer of segments for the rim or flange are to have the inner edge fitted into the rabbet, and are made wide enough to make the wood fillet c. The other layers of the flange will not be required to be as wide, but make all segments of the same thickness, which should be about $\frac{5}{8}$ inch, six segments to the layer, and put the work into the lathe before gluing on a layer of segment, and turn the face of the preceding layer true and concentric with the center of the pattern. Fit the segments carefully and use three hand screws to hold each segment while the glue is drying. A wait of about two hours should be allowed between gluing a layer of segments and turning; so take advantage of the noon hour, and overnight.

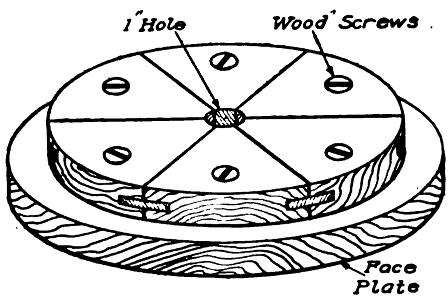


Fig. 196. Web Stock for Disk Crank and Faceplate

Bosses. The work on the hub, wrist-pin boss, and counterweight should be proceeding while building the stock for the web and flange. The hub shall be turned from a solid piece of stock or from glued stock if the dimensions of the hub are too great. The grain of the stock used in the hub and wrist-pin boss should be parallel to the length of the hub.

If positive that the diameter of the cored holes will not be changed, the nowel core prints may be turned as a part of the hub and boss. The cope core prints x and y, Fig. 195, shall be loose on the pattern so that when the nowel mold is rammed these core prints can be removed when the pattern is laid on its back on the mold board. The core prints should be shellacked a different color from the body of the pattern.

The fillet at the base of the hub should be turned from the hub stock, as shown in Fig. 195. The hub is to be turned before it is glued to the web; the fillet, however, should be turned after the hub is in place so as to be tangent to the face of the web.

Counterweight. The counterweight b is next shaped from a single piece, or it may be glued up of 2 thicknesses of $1\frac{1}{8}$-inch stock. In sawing this block to shape, the band-saw table should be tilted so as to give it a draft of $\frac{3}{8}$ inch in 12 inches. Give the inside of the rim, the hub, and the boss a, the same draft as the counterweight, but the outside of the rim should not have a draft of more than $\frac{1}{8}$ inch in 12 inches.

Fillet. When turning on the inside of the rim, a fillet or curve of $\frac{3}{8}$-inch radius, as shown at c, Fig. 195, must be made where the rim joins the disk. Around the counterweight block, and also around the wrist-pin boss, a $\frac{3}{8}$-inch leather fillet can be used.

FILLETS

Usage. The fillets spoken of in connection with Fig. 195 are used in all except the most simple patterns. They consist of a small quarter curve varying in size from $\frac{1}{8}$-inch radius upward, depending on the size of the pattern and the room they can be allowed to occupy. They should be placed in corners so that there may be no sudden changes in the direction of the surface of the casting, which causes weakness, the fillets adding greatly to the strength of the casting. Round corners and fillets should be used wherever possible, as they make a cleaner mold, the metal flows into and through the mold easier, the metal is not so liable to wash away the sand at the corners, and the shrinkage strains of the cooling metal are not so liable to start cracks at the corners.

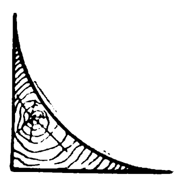


Fig. 197. Section of Wood Fillet

Types. *Wood.* These fillets are made in various ways, the wooden fillet, cut as in Fig. 197, being commonly used for all long straight angles, or for very flat curves to which it can be bent. On large patterns intended for one or two castings, the fillets are three-sided pieces of stock nailed into the corner, giving a chamfered corner to the mold. The molder slicks this corner if necessary.

Wood fillets, where they can be built in, are more durable, and should be used on all patterns intended to be standard, as in Fig. 198.

Wax and Leather. For irregular angles and for short radius curves, beeswax was formerly used, but the modern leather fillet has almost entirely superseded beeswax and other material for this purpose. It is easily applied, shaping and adapting itself to any and all positions and angles. It can be bought in all sizes from $\frac{1}{8}$ inch up, the sizes running by sixteenths.

The method of applying it is to cut it to the necessary length and lay it on a board where the glue can be easily brushed over it. It is then laid in the angle and rubbed into position by means of a dowel rod, the end of which must be rounded. The dowel rod must be of such size as to impart the required curve to the soft pliable leather fillet. As soon as the fillet is rubbed into position, all surplus glue must immediately be wiped off before it sets. This is easily done with a small piece of waste or a rag dipped in the hot water of the outer gluepot and wrung out nearly dry, care being taken not to wet any part of the pattern more than can possibly be helped, after which it must at once be wiped dry. These leather fillets will be found more pliable and more easily placed and rubbed into position if the glue used is first allowed to cool slightly. Very hot glue stiffens and crinkles the leather, causing it to work hard.

Putty. For patterns intended for temporary use, fillets made of linseed oil putty are often used. While this type takes some days to become hard, it is very low in cost and can be used for patterns of this class to good advantage.

ECONOMICAL CONSTRUCTION

Coring to Obviate Machining

Example of Faceplate. It is sometimes advisable to use cores even if it is quite possible to construct the pattern so that it would core its own holes. This is the case where it is desired that the

faces of the casting and the holes shall be smooth and as true as possible without expensive machine work. The finished faceplate of an engine lathe, illustrated in Fig. 198, is a good example of such work.

It will be readily seen that the pattern for this casting could be put in the sand and withdrawn from the mold, leaving the sand standing where the holes are located. The trouble that arises from this method is due to the fact that, when the metal is poured and allowed to flow about the fragile projections that are left to form the holes, the sand washes away, so that the holes in the casting are

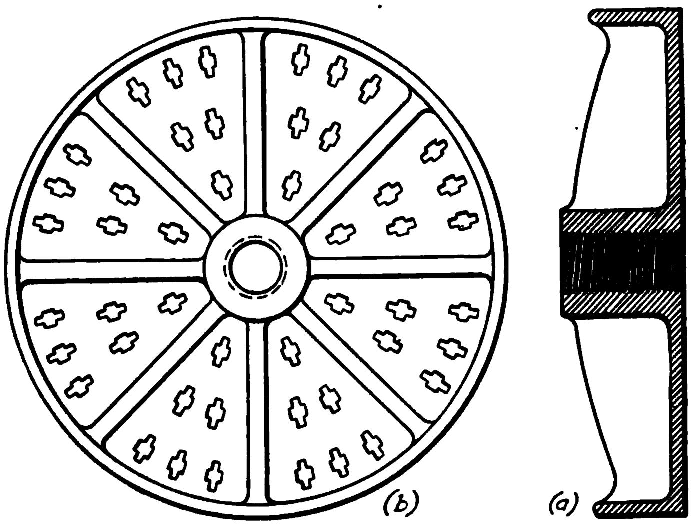


Fig. 198. Typical Metal Faceplate

irregular and much smaller than those in the pattern. For these reasons the holes should be cored, as the core sand is firm and better able to resist the washing action of the flowing metal.

Core Prints in Drag. Where a large flat surface is to be given a finish, it is desirable that the metal should be as clean and free from sand and blowholes as possible. As the iron has a greater specific gravity than the sand of the mold, all particles of sand that may be washed away and all gases generated, rise to the surface of the molten metal. Those imprisoned by the cooling of the iron form the dirt and blowholes that disfigure the completed casting. In a casting such as the faceplate under consideration, it is desirable

that the face should be upon the lower side when the metal is poured as it is to be planed smooth and should be clean iron. For the sake of convenience in setting the cores, the prints are put upon the face and make their impress in the sand of the drag.

Construction. The construction of the web, rim, and hub is to be very similar to that used in making the disk crank, Fig. 195. If the

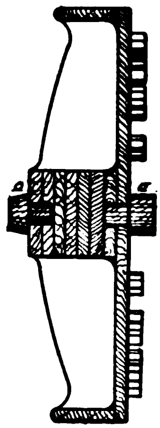


Fig. 199. Section of Pattern for Faceplate, Fig. 198

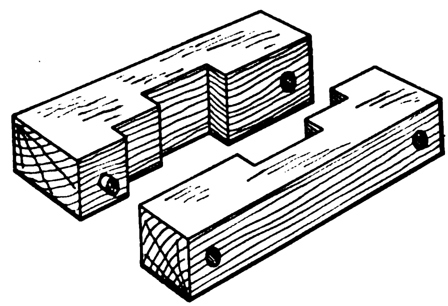


Fig. 200. Core Box for Faceplate Slots

diameter is more than two feet, the grain of stock used in the web should be parallel to the radius. Each sector as it is fitted should be screwed to the wood faceplate, leaving a space of $\frac{1}{16}$ inch between each to allow for the swelling and shrinking of the stock. The ribs are fitted and fastened in place after the lathe work is com-

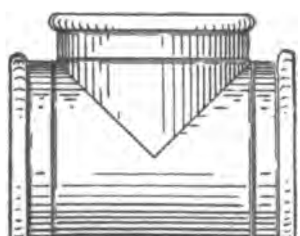


Fig. 201. Tee Pipe Fitting

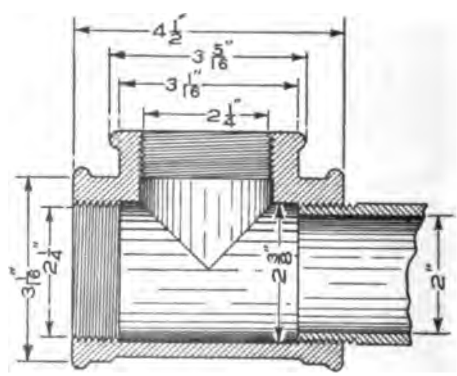


Fig. 202. Section of Tee

pleted; one extra rib should be furnished the molder for mending up the mold. Leather fillets are to be used in the corners made by

the ribs. Iron draw plates are to be fitted in both ends of the hub, at *a*, Fig. 199. The core box for the cores making the holes in the web is shown in Fig. 200.

Molding. In molding, a threaded rod is passed through the cope mold, into the draw plate in the cope end of the hub. It is securely fastened above the cope flask, so that the pattern will be drawn from the nowel with the cope. By rapping on this draw iron, the pattern can be rapped so as to obtain a perfect draw from the nowel mold. After the cope mold has been turned over, the pattern is drawn as usual and any mending required to the mold is facilitated by the extra rib furnished.

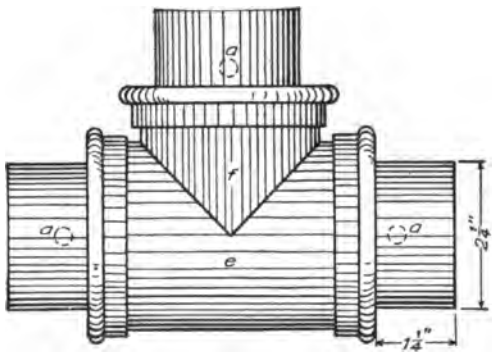


Fig. 203. Elevation of Completed Pattern for Fig. 201

Examples of Simplified Work

T-Pipe Connection. Many patterns which at first may seem to be quite formidable, will, after a little study, resolve themselves into a few very simple parts, nearly all the work for which may be done in the lathe. Of this the T-pipe connection shown in Fig. 201 is a good illustration. A sectional view of the casting, threaded and having a pipe screwed into the right-hand end, is shown in Fig. 202.

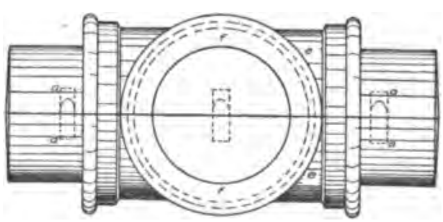


Fig. 204. Plan View of Completed Pattern for *Tee*

The completed pattern for this casting is illustrated in Fig. 203, with its core prints *a*, *a*, and *a*, and must be parted, as shown in Fig. 204. The entire pattern may be made at a single turning, as illustrated in Fig. 205. The preparation of the wood for this pattern is similar to that described for the pattern, Fig. 151, of the brass bearing.

End Fastening. Some device should always be used at the ends of stock glued in this manner to assist in making a firm joint. The metal corrugated fastener is best suited for most requirements. In

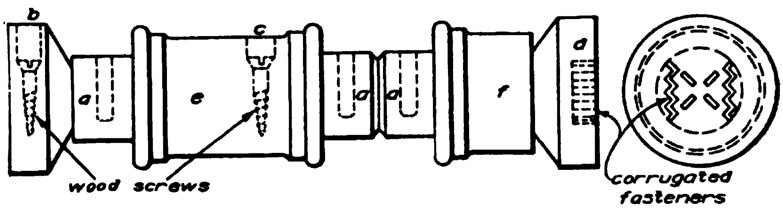


Fig. 205. Pattern for Tee, Fig. 201, as Mounted in Lathe

some cases a flat head wood screw can be inserted at each end, Fig. 205, and the form of the pattern may require a wooden screw to

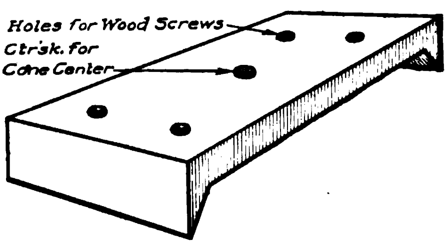


Fig. 206. Steel Center Plate

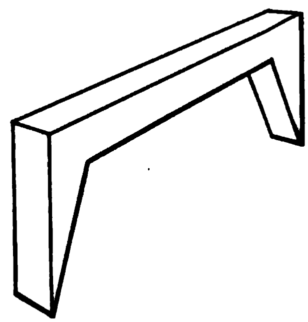


Fig. 207. Steel Pinch Dog

be inserted near the center of the work to prevent its springing open at the center, due to the centrifugal forces at high revolutions.

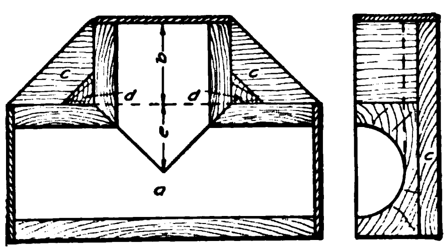


Fig. 208. Core Box for Tee

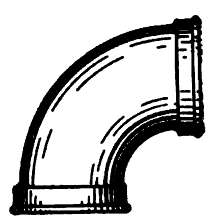


Fig. 209. Elbow Pipe Fitting

Lathe Mounting. In mounting heavy split patterns in the lathe, a special metal dog should be provided, and one such as in Fig. 206 will be found to meet most requirements for this class of

work. In using this dog, which is also the center on which the work revolves, cone lathe centers should be used, and a steel pin should be bolted to the lathe faceplate and inserted in a hole in the end of the stock to drive the work. Several holes can be counter-

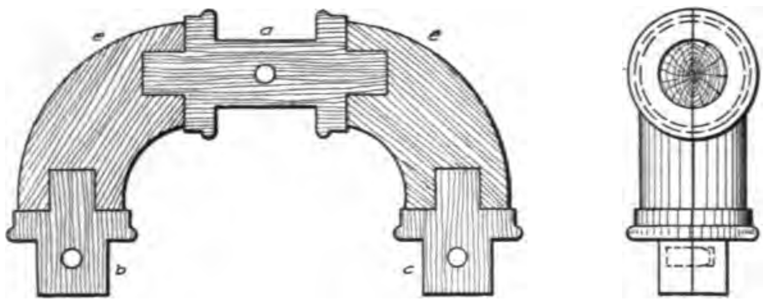


Fig. 210. Section of Double-Elbow Pattern

sunk in these metal lathe dogs when parts of the pattern are to be turned on several centers. The metal pinch dog, Fig. 207, is not adapted for lathe work, as it is liable to fly out when the work revolves, endangering the operator.

Jointing. When the turning is completed, it is only necessary to cut a V-shaped opening into the two halves of *e*, into which the part *f* is to be fitted and glued. When the glue has set and is sufficiently dry, the joint may be further strengthened by nailing, or by inserting and screwing a thin metal connecting plate flush with the parting side of each half of the pattern. This, however, will be necessary only when patterns are large and heavy, or when unusual strength is required.

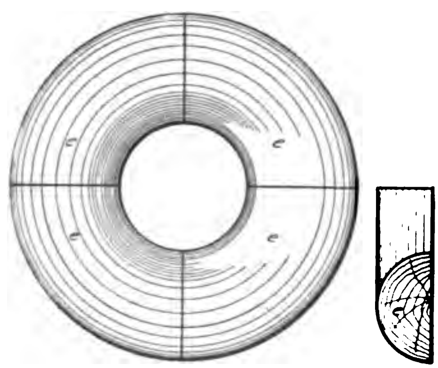


Fig. 211. Method of Turning Up Elbows

Core Box. The core box for this pattern, as will be seen in Fig. 208, is the usual half box and is made by working out the box in one piece long enough to make the two parts *a* and *b*. The two parts are united by cutting a V-shaped opening in the part *a* and fitting *b* into it in the same way as described for the pattern. The

whole is then glued and screwed to the board *c*, and the two triangular blocks *d* and *d* are glued in the angles to add strength to the completed box. In case the pattern is for a very small pipe, 1½ inches or under, the part *b* may be abutted against the side of *a*, as

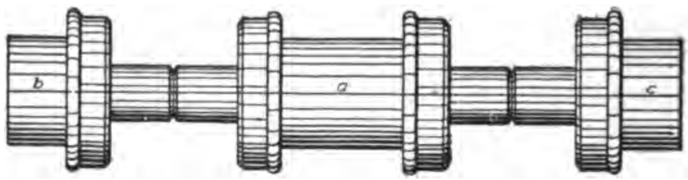


Fig. 212. Turned-Up Flanges and Core Prints

shown by the dotted line, and the side of *a* at *e* cut away to the same curve as *b*, giving the same results as in the former method.

Pipe Elbow. The pattern for the 2-inch elbow, Fig. 209, is another illustration of how such work may be simplified, and time saved, by doing the greater part of the work in the lathe.

Double Pattern. As these elbows are usually cast in large numbers, the patterns should be made double, as shown in Fig. 210.

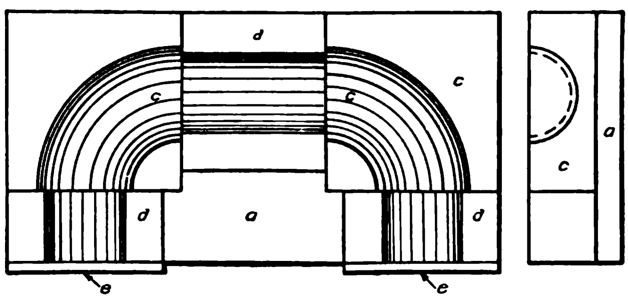


Fig. 213. Construction of Core Box for Elbow Fitting

To construct the double pattern, a ring is first turned like Fig. 211, a cross-section of which is a semicircle, as shown in the lower right-hand corner of the drawing. This ring is cut into quarters, and the four pieces *e*, *e*, *e*, and *e* make the quarter turns for the two halves of the double pattern.

The ends, including the core prints and connecting tenons, are turned in one piece, as shown in Fig. 212, the stock for which is prepared, with the inserted dowel pins all in position in the same manner as described for the T-pattern, Fig. 205. The quarters *e*, *e*, *e*, and *e*, Fig. 211, are clamped together two and two, and the ends

carefully bored to receive the tenons which are then glued in position and further strengthened by a wooden screw.

Core Box. In Fig. 213 the core box for this double pattern is shown, and, as will be seen, the most difficult part of the work can be done in the lathe. Fig. 214 shows two pieces jointed and clamped together which must be screwed to the faceplate of the lathe and turned out to make the two corners *c* and *c*. The three straight parts *d*, *d*, and *d* are worked out in one long piece and afterward cut to the required lengths, after which the five pieces are glued and screwed to the board *a*. The ends *e* and *e* are next put on and the required half-core box is complete.

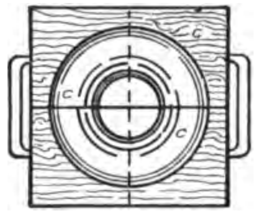


Fig. 214. Part of Core Box as Turned

Supported Core. Another reason why the pattern for pipe elbows should be made double is that otherwise the core prints would require to be made of great length in order to balance, sustain, and keep the heavy core in position; the tendency being to sag in the middle, or float on the molten iron, and thus make the upper side of the casting too thin, all of which is avoided in the double pattern.

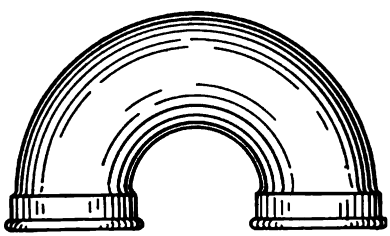


Fig. 215. Return-Bend Pipe Fitting

Fig. 216. Section of Pattern for Pipe Fitting

Return Bend. A pattern for the return bend, Fig. 215, may be built up and constructed in the same manner as described for the elbow; the semicircular returns, not only for the pattern, but also for the core box, being turned in the lathe, together with the ends and core prints for the pattern. As there will be no middle support

for the core in this case, the core prints must be made as shown in the half pattern, Fig. 216, of sufficient length to balance the heavy semicircular core, and also to keep it in its true position in the mold.

Screw Chuck. The small wood lathe chuck, a vertical section of which is shown in Fig. 217, will serve as a simple illustration of

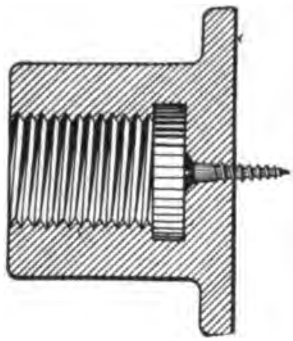


Fig. 217. Screw Center Lathe Chuck

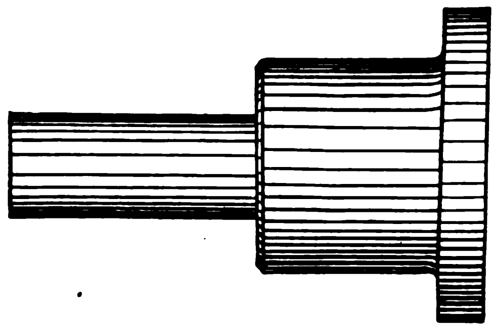


Fig. 218. Appearance of Pattern of Lathe Chuck

the long core print and balanced core. The casting must be countercored; that is, the cored opening must be enlarged at the forward end, adding to the size and weight of that end of the core, which, as will be seen, has no support except that afforded by the extra length of the core at the opposite end. The pattern for this chuck is shown

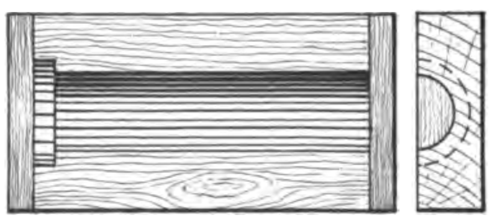


Fig. 219. Core Box for Lathe Chuck Pattern

in Fig. 218, and the core print must have a length at least twice as great as the depth of the hole in the chuck. The core box is shown in Fig. 219.

Deep Flanges. When pipes or cylinders are of moderate size, with deep flanges for bolting together, Fig. 220, the flanges for the pattern are turned out of a separate disk, as shown in Fig. 221, and

firmly glued and nailed on over the core prints and against the ends of the main body of the pattern; the core print being made of suffi-

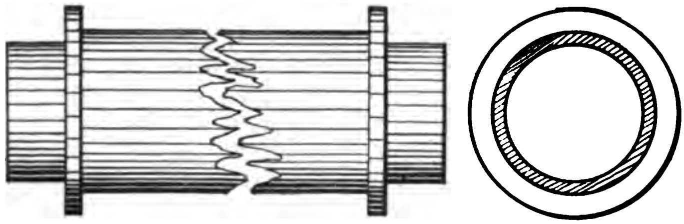


Fig. 220. Flange Pipe Pattern

cient length to receive the flange. A recess is sometimes turned in the inside end of the core print to receive the inner edge of the flange,

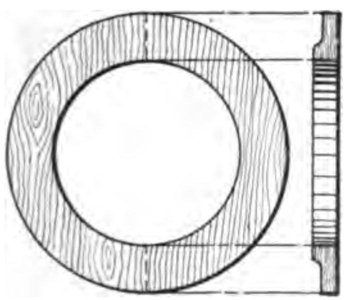


Fig. 221. Construction of Flanges for Pipe Pattern

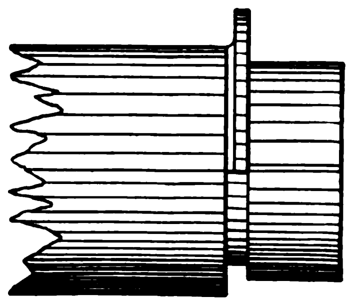


Fig. 222. Diagram Showing Recess for Flanges in Pipe Pattern

as shown in the diagram, Fig. 222; it can easily be seen that when the flange is fitted therein, it adds greatly to the strength of the joint.

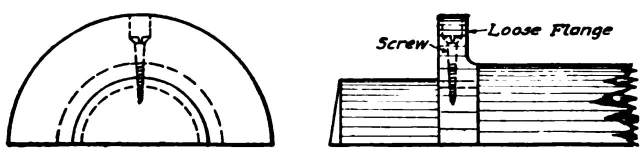


Fig. 223. Interchangeable Flanges on Pipe Pattern

Flanges are often fastened to the pipe pattern by screws only, so that flanges of different diameter can be attached, Fig. 223.

Stock. The flanges should be made by gluing up three pieces and crossing the grain of the pieces so that the grain of each will run at right angles to that of the adjacent one. In gluing pieces together

for thin disks, three pieces should always be used. Two thin pieces glued together will always warp.

A still better and stronger method of making large flanges is to cut out segments, five or six for each course, and fit and glue up on a chuck and faceplate in the same way as described for the handwheel rim, Fig. 173. Two or three courses are used for each flange, which, after being turned to the required size and form, is sawed in two with a very thin saw, and each half fitted into place on the pattern.

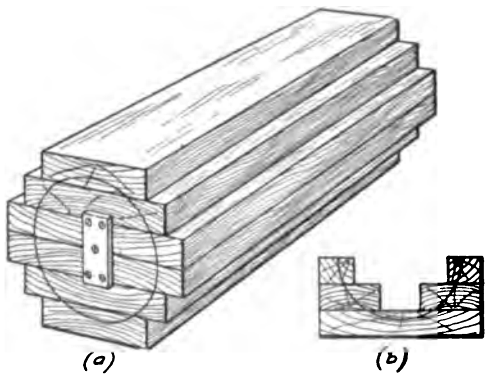


Fig. 224. Method of Assembling Wood for Large Pipe Pattern

Fig. 225. Light Pattern Construction for Cylinder

Large Cylindrical Work. The patterns for the larger pipes or columns are to be glued up, as shown in Fig. 224, and, for turning, the two halves are held together by means of lathe dogs such as shown in Fig. 206. The treatment of this glued up stock in the lathe, is the same as employed in turning the small pipe shown in Fig. 220. The method of constructing the core box for this or similar patterns is shown at *b*, Fig. 224. Tees, elbows, and other bends and connections, when large, are built up in a similar way.

Hollow Construction. For large cylinders, a much lighter and simpler method of constructing the pattern is shown in Fig. 225. For each half of the pattern the two end disks and the middle semicircular disk are connected together by a strong center bar, which is fitted, glued, and screwed into each, serving not only to strengthen the pattern, but also to hold the connecting dowel pins. When the two halves of the pattern are clamped together, it serves also as a secure means of centering in the lathe.

The staves forming the body of the cylinder are fitted and glued to each other, and screwed or nailed to the disks. After the cylinder has been turned, the core prints and flanges are built up

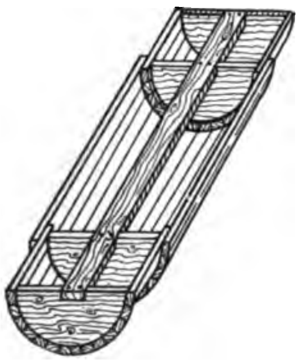


Fig. 226. Slightly Heavier Construction for Cylinder Pattern

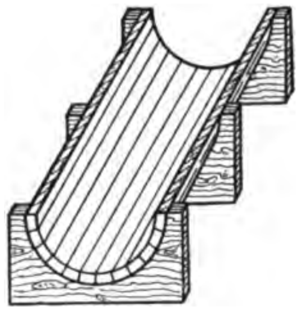


Fig. 227. Typical Core-Box Construction

and turned separately, and glued and screwed to the ends of the cylinder from the inside of the end disks.

Fig. 226 illustrates still another and better method of building up the cylinder and core prints in one piece and completing the hole at a single turning. The core prints, as shown, are staved up first,

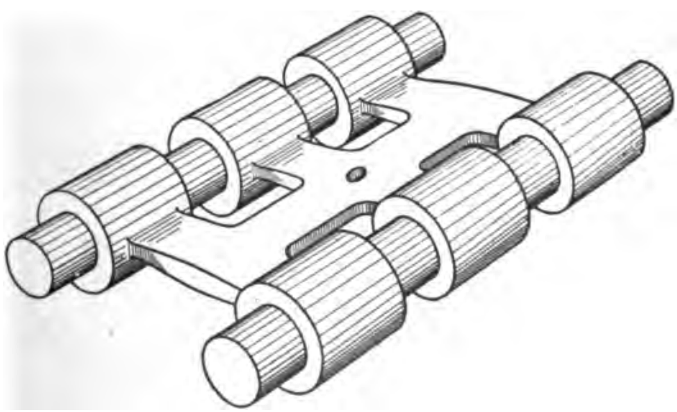


Fig. 228. Gated Pipe-Coupling Pattern

and then the staves to form the body of the pattern are fitted, glued, and screwed, or nailed, over the ends of those which form the core prints. For long cylinders use one, two, or more middle semicircular disks.

A similar construction for the core box is shown in Fig. 227, and is to be preferred to all others, because, if laid out and built to the exact size, the labor required to reduce the staves to a perfect semicircle of the required radius is very little.

Quantity Production. Patterns for such work as pipe fittings would come under the head of standard patterns, as usually these parts are required in large numbers. The present-day practice of molding patterns for the smaller sizes of pipe fittings is to either have a number of similar patterns gated, Fig. 228, or resort to plate molding and stripping-plate molding machines. Some present-day methods of machine-molding pipe fittings are considered in Part III, Pattern Making.

INTRICATE CORING

Globe Valve

Globe Construction. The globe valve, shown in section in Fig. 229, is a good illustration of a pattern in which, while the out-

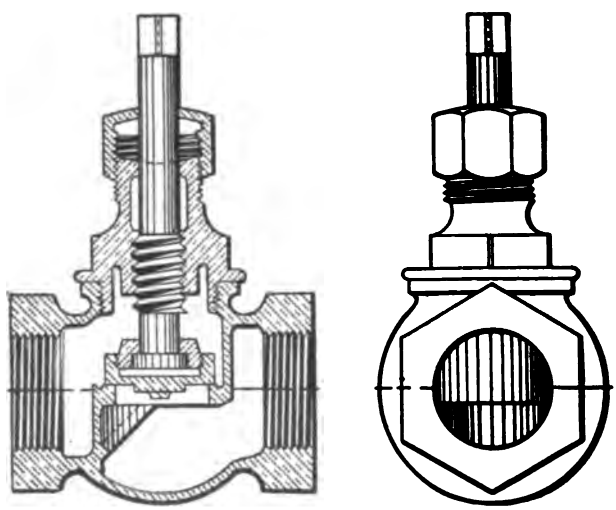


Fig. 229. Section of Blow Valve

side may be very simple, the inside is intricate and requires considerable practice and skill to so construct the core boxes that the core can be withdrawn from them, and at the same time give uniform thickness and strength to all parts of the shell and to the internal partitions.

In Fig. 230 is shown a sectional view of the body of the valve, and in Fig. 231 an illustration of the completed pattern, from which

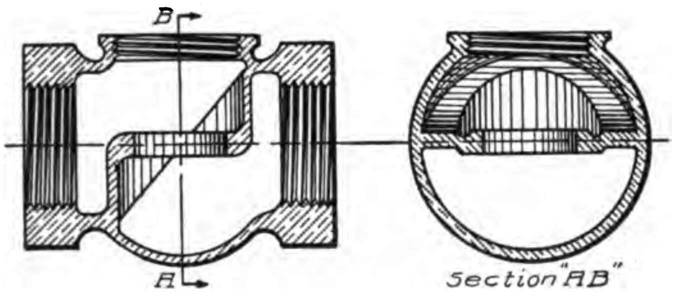


Fig. 230. Section of Valve Body

it will be seen that almost the entire work, with the exception of fitting, placing the dowel pins, and forming the two hexagonal ends,

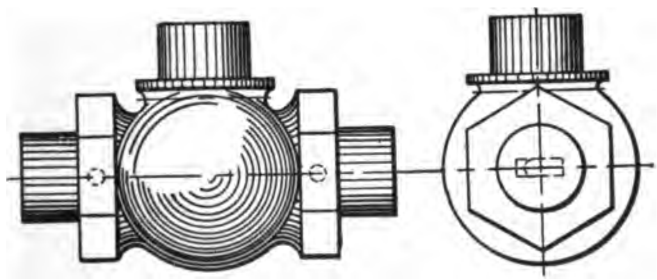


Fig. 231. Appearance of Pattern for Blow Valve

is done in the lathe. The construction is shown in the sectional illustration of the half pattern, Fig. 232. The wood for the two

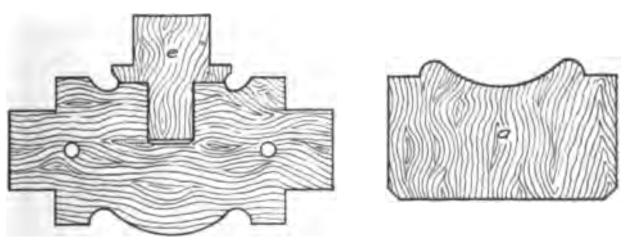


Fig. 232. Sectional View of Pattern and Template for Blow Valve

halves must be of sufficient length to allow for gluing at each end. In turning, the greatest care must be taken to center exactly on the parting line of the two halves.

Use of Template. A carefully shaped template, such as is shown at *a*, Fig. 232, must be used in turning. This template may be made of a thin piece of wood, but for all purposes for which templates are required in pattern making, and their use is necessarily very great, sheet zinc is the best material. It is soft, and easily cut and filed, and does not dull the cutting tools so much as other metals.

Before marking out the template, that the lines may be more readily seen, it should be cleaned with a piece of emery cloth and have a dark coating of the following solution. Dissolve an ounce of sulphate of copper in about 4 ounces of water and to this add 1 teaspoonful of nitric acid. Treat the surface of the zinc with this solution, rubbing on with a piece of waste. A thin coating of copper will thus be given to the zinc—or, similarly, to steel or iron. When applied to finished surfaces they should be rubbed dry, as iron or steel will be rusted.

When the curves of the template will allow of sawing, the zinc template is easily shaped by placing a piece of zinc of the necessary size between two boards and nailing them together. The required shape having been drawn on the upper board, the whole may be sawed to the form required on the band saw or scroll saw, but preferably on the latter, with a fine-tooth narrow saw blade which will give a smoother edge to the zinc. If the boards are firm, the metal will offer no resistance whatever to the saw, nor will the saw be perceptibly dulled. For small curves, lay the zinc on a piece of hard board, and with a pair of sharp pointed dividers the zinc can be scratched half way through its thickness, then by turning it over and placing the dividers in the same center, the other side may be cut in the same way, or so nearly through that it will break off. This affords a truer and more uniform curve than can be obtained in any other way. The legs of the dividers must be stiff and firm so as to be entirely free from vibration. After cutting, the sharp edges of the zinc may be dressed with a fine double-cut file, or better with fine emery cloth or sandpaper rolled over a wooden holder.

The lathe should always be stopped when testing the work with the template, and great care must be taken to make the two ends of the pattern symmetrical. When the turning is nearly completed the template itself may be tested by reversing the ends. If not true, it should be filed to the proper shape.

Branches. The branch *e* must be turned in the same way as described for the main part of the pattern which is pared off, or planed off in a large pattern, to the exact size of the base of the branch, and when the pattern is large and heavy, one or two wood screws should be used in the tenon of the branch to assist in keeping it in place.

In all small and moderate-sized valves the flanges are hexagonal in shape, as shown in Figs. 229 and 231.

Two-Part Core. The core for a globe valve is made in two parts, and the core box for each part must be made in upper and

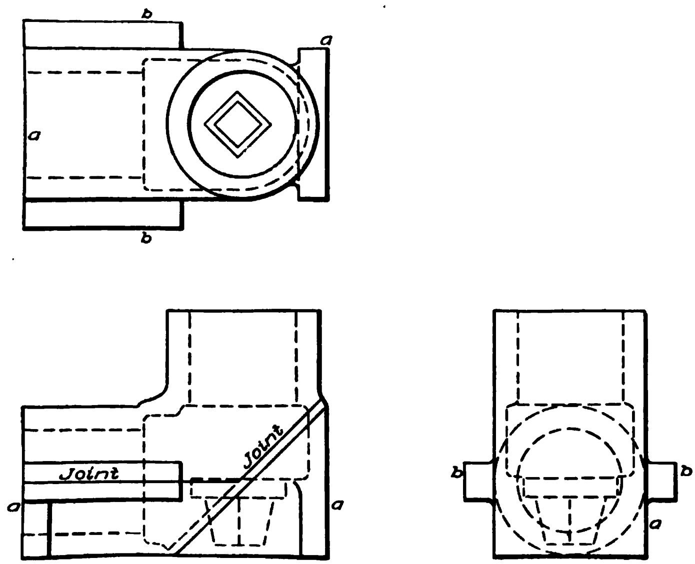


Fig. 233. Upper Iron Core-Box Details

lower halves, making four parts to the core box. This is necessary in order to allow for the removal of the core from the boxes. The internal shapes of the boxes are difficult to illustrate on paper, but if the drawings given in Figs. 233 and 234 are carefully studied in connection with the sectional views of the valve shown in Fig. 230, their shape and construction should be readily understood. Three additional illustrations of the core as made in these core boxes are shown in Figs. 235, 236, and 237.

Forms for Baking. If the form of the core is such that there cannot be a flat side upon which to bake the core, a metal form must

be provided. The drying form can either be placed on the core after that side of the core box has been removed, or it can be the core box itself. For this reason, and because of the necessary wear

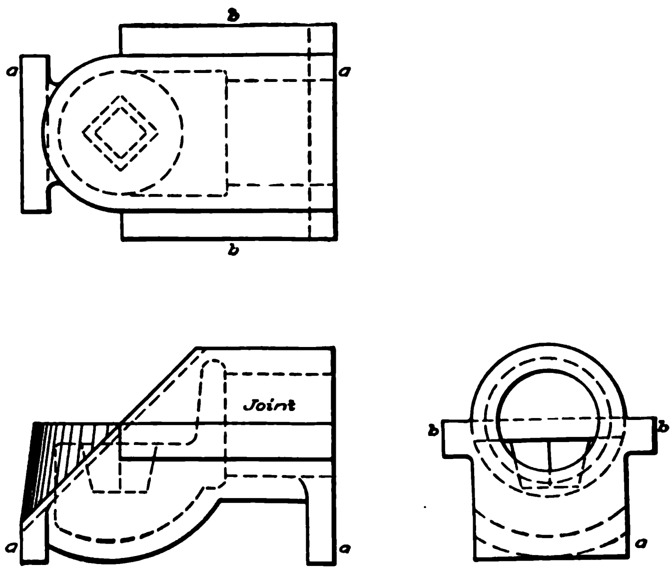


Fig. 234. Lower Iron Core-Box Details

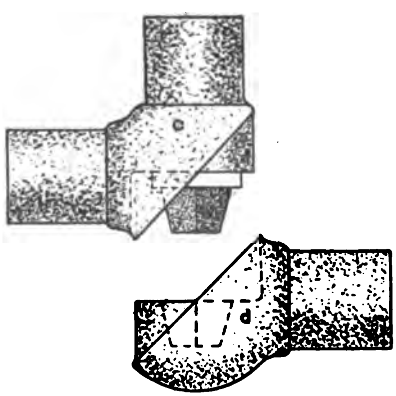


Fig. 235. Dry-Sand Cores before Pasting Together

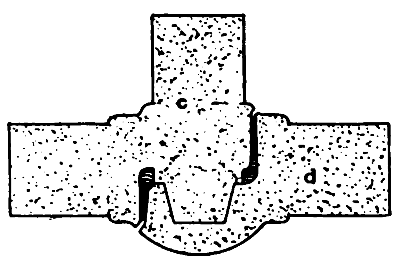


Fig. 236. Sectional View of Dry-Sand Core

and fragile character of wood for boxes of this kind, this core box will be made of iron. The wooden pattern for the metal core box must then have an allowance for double shrinkage, and to avoid

excessive weight, the box is made in the form shown in Figs. 233 and 234. In this form all unnecessary metal is removed, and lugs should be added to the upper part of the core box to align the two parts while ramming the core, as shown at *b*, Figs. 233 and 234. The lower part of this core box, as shown, is to have projections cast on at *a* so that this half can be used for holding the core sand during the baking process. Several drying forms are furnished the core maker, if a considerable number of castings are required.

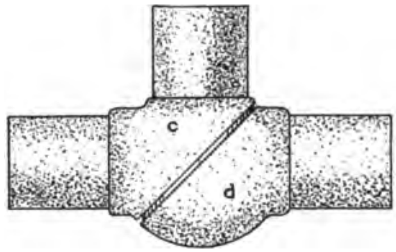


Fig. 237. Assembled View of Dry-Sand Core

Bonnet. Fig. 238 illustrates the pattern for the stuffing box and bonnet of the valve, with core print turned on

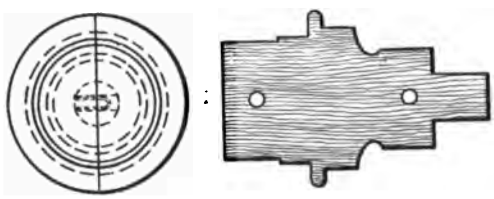


Fig. 238. Pattern for Stuffing Box

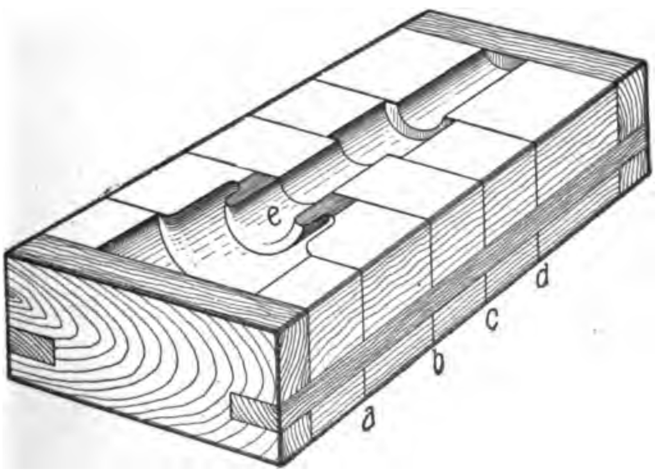


Fig. 239. Core Box for Stuffing Box

each end, which, like the main pattern of the valve, must be parted or made in two halves.

Core Box. Figs. 239 and 240 are illustrations of the core box and core for the stuffing box and bonnet. The process of building this core box is very similar to that used for the bronze bushing shown in Fig. 150. Saw the stock at *a*, *b*, *c*, and *d*. Have the total length of all parts equal the total length of the pattern. Scribe the half circles on the ends of each piece, and gouge to form required. Glue all parts together, saw for splines, and complete as before.

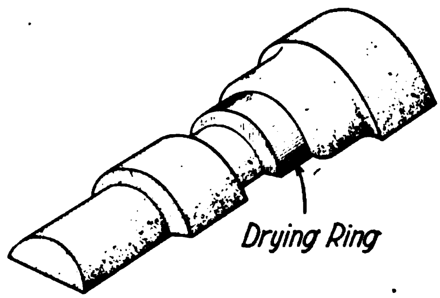


Fig. 210. Half Core of Stuffing Box with Drying Ring in Place

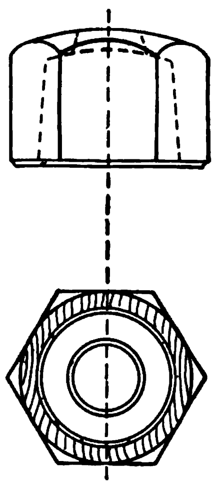


Fig. 241. Valve Stem Nut

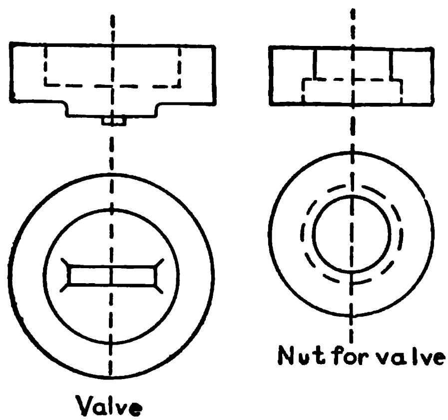


Fig. 242. Details of Valve and Valve Nut

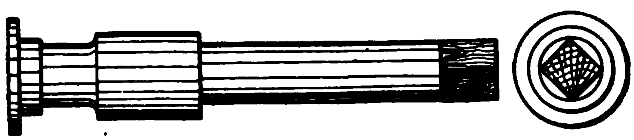


Fig. 243. Valve Spindle. (This pattern is not split)

Drying Ring. A pattern for the drying form or ring should be made to the shape shown in Fig. 239, which is to be fitted into the

core box at *e*. After drying the core, these rings are slipped endwise toward the chamber and then can be easily removed.

Small Parts. The pattern for the nut for the bonnet is shown in Fig. 241, and those for the valve and valve nut are shown in Fig. 242. The patterns should be so made as to form their own cores, as indicated by the dotted lines in the drawing. Fig. 243 is an illustration of the pattern for the valve spindle.

Engine Cylinder

Type of Pattern. The slide-valve engine is built in a great variety of forms. Fig. 244 represents a sectional view of the cylinder of a very common type. At *e*, Fig. 245, we have a cross-section through the steam chest and exhaust port at *AB*, and at *F*, a cross-section at *CD* through the steam port.

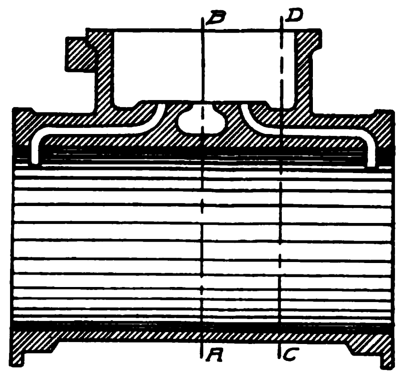


Fig. 244. Section through Slide Valve Cylinder

When the cylinder is small—10 inches or under in diameter—the pattern is usually built up solid, but if more than 10 or 12 inches in diameter it should be built of staves, as shown in Fig. 246. When the size is 30 inches or over, a loam mold is usually made, as is fully described in the section on Foundry Work. The size limit, however, varies greatly in different foundries.

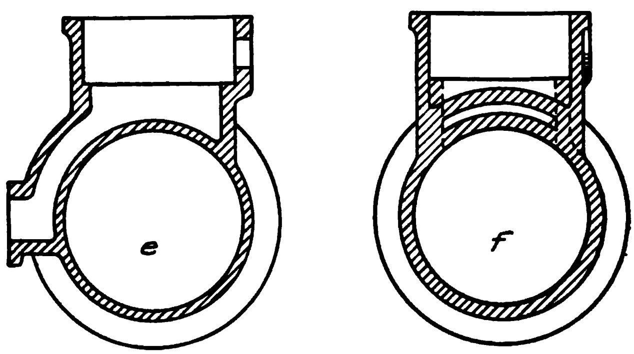


Fig. 245. Sections through Slide Valve Cylinder at *AB* and *CD*, Fig. 244

The construction of the pattern is illustrated in Fig. 246 and needs no description here, it being the same as already given for

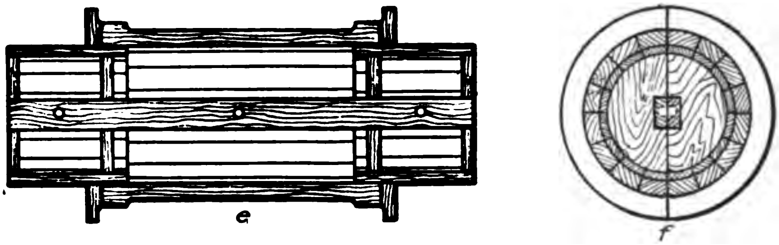


Fig. 246. Section of Cylinder Pattern

Fig. 226. The flanges, however, should be built up of segments of two or three layers each, as shown in Fig. 247. After gluing up to the necessary thickness to make the flange, it is sawed in two halves, jointed, and carefully centered on a wooden chuck, and turned to the dimensions required. The centering must be done with accuracy, or one-half of the flange ring will be larger than the other.

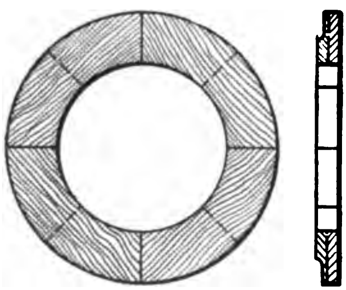


Fig. 247. Built-Up Flange for Cylinder Pattern

Steam-Chest Pattern. The steam chest is next built and fitted centrally on the upper half of the cylinder pattern, as in Fig. 248. The projections *a a*, which give the extra width of metal for the

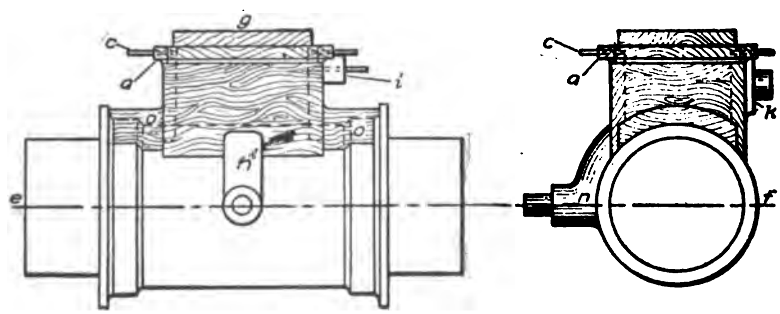


Fig. 248. Two Views of Cylinder Pattern Including Steam Chest

bolts of the chest cover, are left loose, being kept in place by long wires or dowel pins, as shown at *c c*, so that they can be withdrawn

separately from the mold after the main part of the pattern has been taken from the sand. These four strips should be recessed into the corners of the chest $\frac{1}{4}$ inch, as shown by the dotted lines, to prevent them from being rammed out of place after the dowel pins are taken out. The boss *i* for the valve-rod stuffing box, and also the boss *k* around the steam-pipe opening, must be loose so as to be taken out of the mold after the pattern has been removed. The pieces *o o* at each end of the steam chest, which form a thickness of metal over the steam ports, are then fitted in place, as is also the exhaust passage *n*, which must be parted on the line of parting of the two halves of the cylinder pattern.

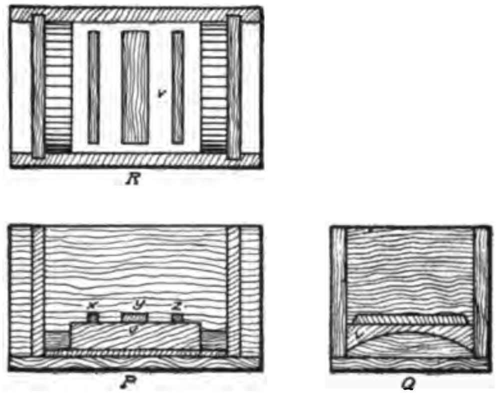


Fig. 249. Views of Core Box for Steam Chest

Core Boxes. *Cylinder.* The main core box for the cylinder is made in the same way as has been already described for Fig. 227.

Steam Chest. The steam-chest core box is shown in Fig. 249, in which *P* is a side view, one side of the box being removed to show the valve seat *v*, and the core prints *x*, *z*, and *y*, which form recesses in the core into which the upper ends of the two steam-inlet cores and the central exhaust-passage core are placed. *Q* is an end view of the box with one end removed, and *R* is a view looking into the box from above.

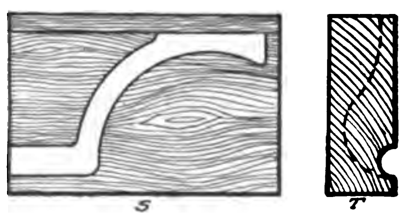


Fig. 250. Exhaust Port Core Box

Exhaust Passage. For the core forming the exhaust passage, two half-core boxes, one right and one left will be necessary. One-half of this box is illustrated at *S*, Fig. 250, as also a sectional view at *T*. The dotted lines show the manner in which the passage is widened to retain the full size of the opening throughout.

Inlet Passages. Only one core box will be needed for the two steam ports. Three views of the box are given in Fig. 251. At *G* one side is removed, giving a side view of the construction of the box. *H* shows a cross-section through *G* with the end *u* removed, and *F* is a view from above. The core is swept off on the upper side for the length of *cc*, and the bar *ee* as well as the end *u* must be movable so that the core can be taken from the box. Both ends of the core change from circular into straight parts just at the entering of the cylinder and at the entering of the steam chest.

Facility of Construction. The entire set of patterns is simple and easy of construction if carefully made drawings are furnished to work from; the time and labor required depending entirely upon the size of the cylinder.

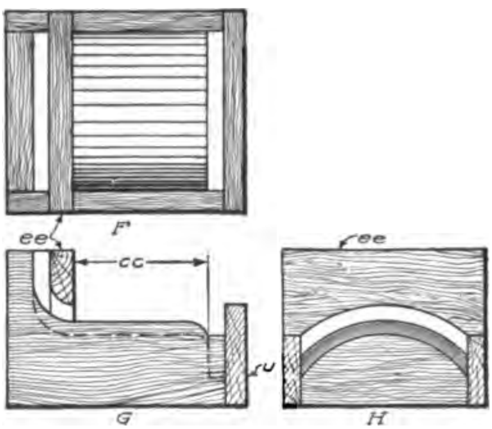


Fig. 251. Views of Live Steam-Port Core Box

Separated Steam Chest. In some slide-valve cylinders, the steam chest is cast separate and bolted to the cylinder, thus affording free access to the valve seat *v* and a better opportunity for finishing and fitting. In this case, the main cylinder core and the two steam-inlet cores are made together in the same box, as illustrated in Fig. 252, in which one side of the core box is cut away to a depth of one-half of the length of the steam-port openings, or to the line *cc*, which must be just one-half of the inside width of the box, as shown at *H* and at *F*, Fig. 251. The part which has been cut away is replaced by the three blocks *a*, *a*, and *b*, which are shaped to give the required size and form to the steam-port cores. These blocks are fastened by dowels, loosely, to the main part of the core box, and, after the core has been rammed up, the whole box and core is turned over on its face and the main part of the box is lifted off, after which the two loose blocks *a* and *a* can be drawn away endwise and the block *b* can also be lifted out with ease.

GEAR WHEELS

Accurate Teeth Required. In this special class of pattern work, the greatest accuracy and care must be taken, not only in building up the rim of the wheel, but in fitting and placing on the rim the blocks out of which the teeth are to be formed, and most of all in laying out the teeth regularly and accurately on the tooth blocks. A pattern for a gear wheel whose teeth are carelessly made is almost

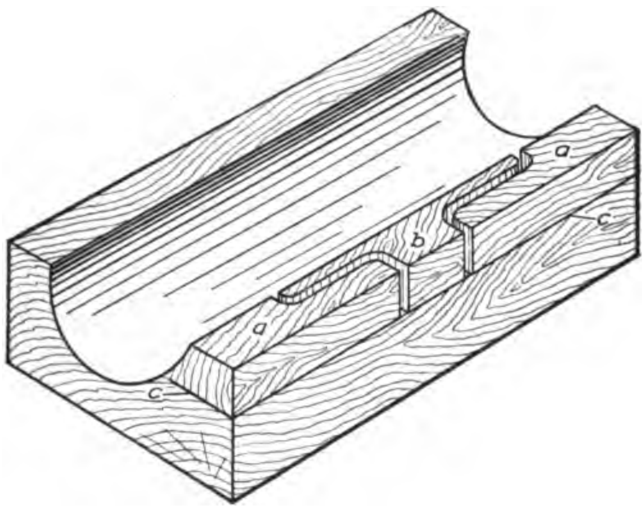


Fig. 252. Bore and Live Steam-Port Core Box as Arranged for Small Cylinders

worthless, the time lost in chipping and filing for the purpose of correction being too great to allow the use of such a pattern.

Teeth Machine Cut. It is common practice in some pattern shops to build the pattern with the teeth stock fastened to the rim permanently, and having the teeth cut in a gear-cutting milling machine. To insure greater accuracy and smoother running gears, it is now the custom in many shops to have the wooden pattern made in the form of a blank without teeth, from which a metal pattern is cast. This cast pattern is turned up and placed in the milling machine where the teeth are cut and spaced with accuracy and to the exact form of tooth required. This metal pattern is used without draft. This method of making gear patterns, however, is expensive, and is used only when many wheels are to be cast of the same size and number of teeth from the same pattern, and, as in the

case of pulleys, the wooden pattern is still used for all special sizes of gears.

At its best, the cast gear can never compete with the cut gear for smoothness of running and the efficient transmission of power. The modern machine practice calls for machine-cut gears, and consequently the cast gear is only for certain classes, as slow-moving machines where considerable backlash can be allowed, and when the teeth can be of such size as to be molded easily. For these reasons, the present-day pattern maker rarely ever gets so far as to cut the teeth of the gear pattern. However, several methods of constructing the arms, rims, and teeth sections of these patterns will be considered, and a few hints given as to the best methods of construction.

Patterned Teeth. *Form.* As the form of the tooth used by the draftsman will play no part in the construction of the pattern,

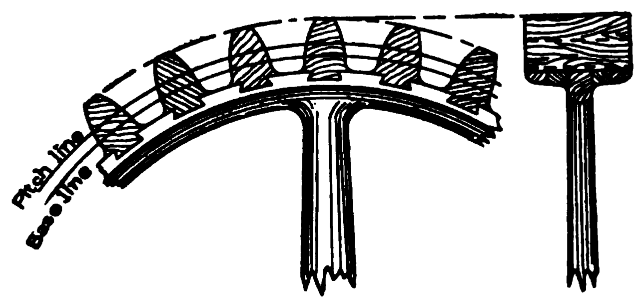


Fig. 253. Wood Spur Gear Showing Teeth Dovetailed to Rim

we think it would be out of place here to enter into a discussion of the relative merits of the single-curve, double-curve, or other form of tooth. The single-curve or involute tooth, however, has the great advantage of being the only form of gear which can be run at varying distances between axes and transmit an unvarying velocity and amount of power. The common contention that two gears will crowd harder on their bearings when the single-curve or involute form is used has not been proven in actual practice. The practical methods for obtaining the curves for either the involute or for the epicycloidal tooth, the two forms in most common use, are taken up in Mechanical Drawing. In the illustrations here given, the single-curve form of tooth is used.

Fastening Methods. In the construction of gear-wheel patterns, the methods employed in making and fastening the tooth, or the blocks out of which the teeth are to be formed, to the rim of the wheel vary greatly. It was formerly the custom to dovetail the tooth into the rim of the wheel, as shown in Fig. 253. This was the case especially when the teeth were large, as in 2-pitch or larger. This is, however, an unnecessary expense and a waste of time, and, in addition, the cutting of the dovetails and the driving home of the dovetailed tooth often have the effect of distorting the rim to some extent.

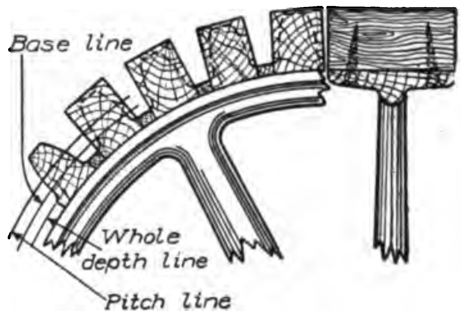


Fig. 254. Wood Spur Gear with Teeth Fastened with Wood Screws, Filler Pieces Glued between Teeth

A better, or at least a more economical, method, is to fit the tooth blocks as shown in Fig. 254, which for strength and durability is

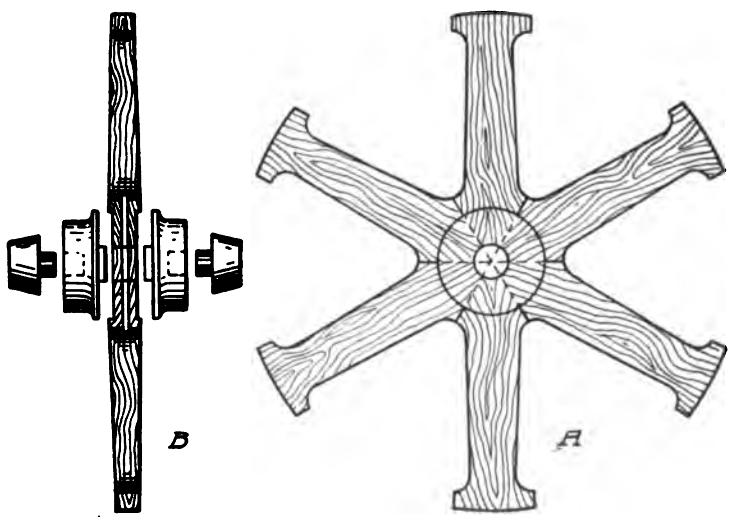


Fig. 255. Arms, Hub, and Core Prints of Spur-Gear Pattern

found to be in no way inferior to dovetailing, and the saving of labor and time is very great. In this method we have always the advan-

tage of a smooth clean fillet at the root of each tooth, and having the grain of the wood, not only for the fillets, but also on the whole depth circle, run in the same direction as the grain of the wood which forms the tooth. This means a smoother pattern, more easily molded, and a better casting. In the former method, Fig. 253, it is almost impossible to form a fillet on each side of the tooth, as it runs off to a thin featheredge which continually splinters and chips off; still further, the bottom of the tooth space, that is, the whole depth circle is the rim of the wheel, composed of layers of segments with changing grain which will not mold so smoothly as in the second method.

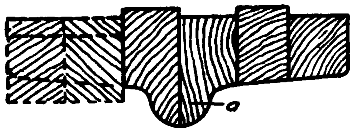


Fig. 256. Section Showing Rim Formation

The blocks for the teeth shoud always be cut in strips 2 or 3 feet in length, in order to season the wood so far as is possible while other parts of the wheel are being constructed. Only straight-grained wood should be used for teeth.

Rim and Arms. The segments for building up the rim should be cut out next, then the arms put together and shaped as required. It is a good plan to fasten the arms central to the faceplate of the lathe, and to turn out a recess, say $\frac{1}{16}$ inch or $\frac{3}{32}$ inch deep, to receive the hubs, as shown in Fig. 255. This makes a stronger connection and does away with the trouble of fitting and connecting the hub, with the thin featheredge of the hub fillet, to the surface of the web of the arms. The same method is of great advantage when fitting the hubs of pulleys and other wheels.

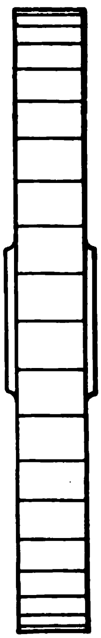


Fig. 257. Section Showing Facing of Tooth Backs

The arms must be put together, with inserted tongues in the joints, as illustrated and described in connection with Fig. 171; and if they are to be worked to an elliptical section, it is easier to do this before fixing them in the wheel. At A, Fig. 255, the construction of the arms is shown, and at B the core prints, hubs, and arms, with the manner of connecting these parts.

After building up enough courses of segments to equal half the

width of the rim plus half the thickness of the arms, the inside only of this part of the rim is turned out to the required shape, including the central rib *a*, Fig. 256, which must be of a thickness just equal to the thickness of the ends of the arms. The recesses to receive these ends are then cut into this half rim, and the arms fitted and glued in place, but not so tightly as to strain the rim and cause it to spring after it is removed from the chuck. Refer also to the method of building stock for arms and rims used in making the 20-inch pulley, which has the advantage of requiring less labor. The remaining courses for the rim are now fitted and glued on, and the rim turned and finished to the required size and shape.

Forming Teeth. *Placing Blocks.* The face should be glue sized to prepare it for the blocks which are to form the teeth of the gear. After sizing and removing the raised grain of the wood, the periphery of the wheel must be spaced for the required number of teeth. With a try-square and very sharp awl draw lines through the points obtained by the spacing, as shown in Fig. 257. Should the teeth be of moderate size, say 3-pitch or less, the tooth blocks should be glued on so as to meet each other on the rim of the wheel, as shown in Fig. 258, and, not being screwed on, must be nailed with brads from the face of each tooth into the rim after being shaped and finished.

Fig. 258. Spacing for Teeth

Each block must be so fitted as to reach only from line to line, Fig. 257, care being taken to have each block parallel to and coincide with its own line, reaching exactly to the line. When all the blocks are placed and glued, the wheel is returned to the lathe and the periphery turned off straight and to the required diameter for the addendum or tops of the teeth. The ends of the blocks are also turned even with the edge of the wheel rim, and before removing from the lathe, a circular line must be drawn on the ends of the blocks, on both sides of the rim, indicating the whole depth of the teeth. The use of this line will be explained later; it is the only circular line needed for laying out, or for working out the teeth.

When the teeth are large, a tooth block is first fitted on and screwed from the inside of the rim, as shown in Fig. 254, one edge of the block touching, but not covering its line on the face of the rim. The thin strip is next fitted, glued, and bradded against the block, with the opposite edge of the strip reaching just to, but not covering the next line. A second tooth block is fitted and screwed in place, then a second strip, and this alternate placing of blocks and strips is continued until the surface of the rim is covered, having a block and strip for each tooth required. Care must be taken not to allow any glue to get between the blocks and the strips when gluing and nailing the strips on, as each block must be taken off, one at a time, after being laid out, to work the tooth to shape.

Spacing. When all the blocks and strips are in place, the wheel must be returned to the lathe and the face of the blocks turned to the diameter required for the addendum or tops of the teeth, and the ends of the blocks also turned even with the rim. The whole depth or clearance circles are marked, one on each side, while revolving in the lathe, as explained for a wheel with smaller teeth. All parts of the rim should now be made perfectly smooth with fine sandpaper, using a holder or block to prevent rounding the corners or angles of the tooth blocks.

Beginning at the middle of a block, space the required number of teeth on the periphery of the tooth blocks, and should the first trial not result in even spaces, the trial spacing must be continued until the greatest accuracy has been obtained, that is, until all distances from point to point are exactly equal. Through each spacing point, found as above, very sharp but light lines are drawn across the face of the blocks, as was shown for the wheel rim in Fig. 257. When drawing these lines it will be found best to draw along the inside edge of the try-square blade instead of the outside as is usual. The reason for this is that on small or medium-sized wheels a much firmer base will be given for holding the square, and more accurate lines will be the result. A coat of shellac brushed over the ends and faces of the blocks, if sandpapered smooth after being allowed to dry, will greatly assist in laying out the teeth, hardening the surface, and enabling sharper lines to be drawn.

Tooth Template. A template must next be made of the exact form of the tooth required. This will always be given full size in

the detail drawings furnished to the pattern maker. Should the wheel be of small diameter, the template may be laid out and cut on the end of a long strip of zinc, but it is better to fasten the template to the end of a wooden bar, as shown in Fig. 259, a narrow slot having been cut through the back end of the zinc to allow of exact adjustment to the diameter of the wheel. This wooden bar is hung centrally on a peg or dowel which must be placed exactly in the center of the hub. For this purpose it is customary to use a block of wood as a temporary hub, the center of which may be easily found from the periphery of the blocks by the dividers. A very slight sharp notch is made in the exact center of the end of the tooth template, which must be radial to the hole in the opposite end of

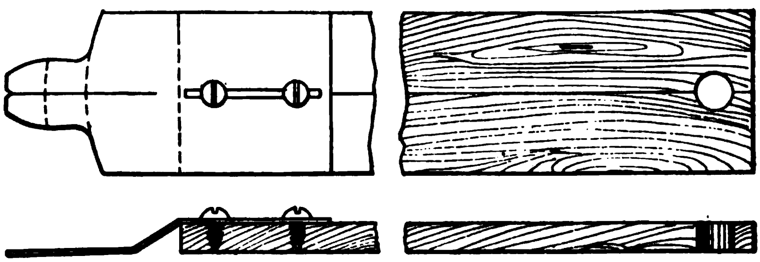


Fig. 259. Template Used to Lay Out Teeth of Spur Gear

the bar on which the template revolves. This notch is shown in Fig. 259.

To use the template, place it over the center pin and bring the notch exactly in line with one of the spacing lines on the outside of a block, and with a very sharp pointed awl mark the tooth on the end of the block. Then swing the template to the next line and mark as before, continuing the process until a tooth has been laid out on the end of each block. The wheel is now turned over and the same process repeated on the other side. It will be readily seen that if the spacing lines have been squared across the face of the wheel with accuracy, the teeth laid out on the two sides will be true and perpendicular to each other, a spacing line forming the exact center of each tooth, and for this reason these lines should always be very light but sharp and clearly defined.

Cutting and Paring. For convenience in cutting and paring, a second series of lines should now be drawn across the face of each

block connecting the extreme ends of the lines which describe the shape of the tooth on each end of the block. Should the wheel be small and within the capacity of the band saw, all superfluous wood may easily be removed from between the teeth.

If the band saw is sharp and evenly set, and the operator skillful, the teeth may be sawed so as to need but very slight correction with the paring chisel and gouge. As the hubs usually project beyond the rim on each side of the wheel, they should be left loose and removed before placing the wheel on the saw table.

For large wheels and heavier teeth, each tooth block should be unscrewed and removed, one at a time, and planed to the lines marked on its ends and face, after which it is returned to its place before a second one is taken off. This is continued until all the teeth are shaped, when it will be necessary only to construct fillets at the base of the teeth, and also to work each space down to the whole depth or clearance circle, the circle having been drawn for this purpose and also as a guide for bringing all tooth spaces to the same depth.

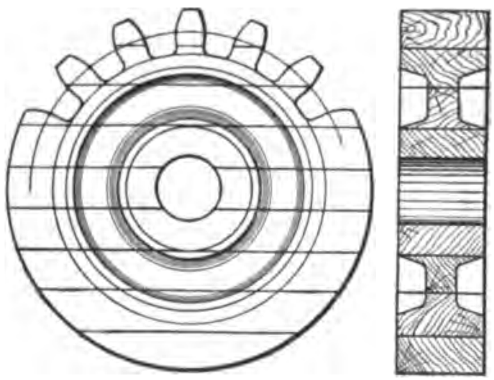


Fig. 260. Section Showing Small Gear Made from Glued-Up Stock

Solid Pinions. Small gears, or pinions, as they are called, are usually made with a solid web instead of arms, and are glued up in solid blocks of end wood, the grain of the entire block running parallel with the face of the teeth. Such an end-wood pinion is shown in Fig. 260. It is turned and the gear laid out and cut in the same way as described for the larger wheels, except that the teeth are not glued on but are cut out in the solid disk.

Bevel Gears

Built-Up Construction. Patterns for bevel and miter gears are built as illustrated at *a* and *b*, Fig. 261. The segments are to overlap

as shown, which is not only a saving of stock, but also saves time which would be required to turn the angular rim from a square construction. It will be best to make a full size layout of a radial

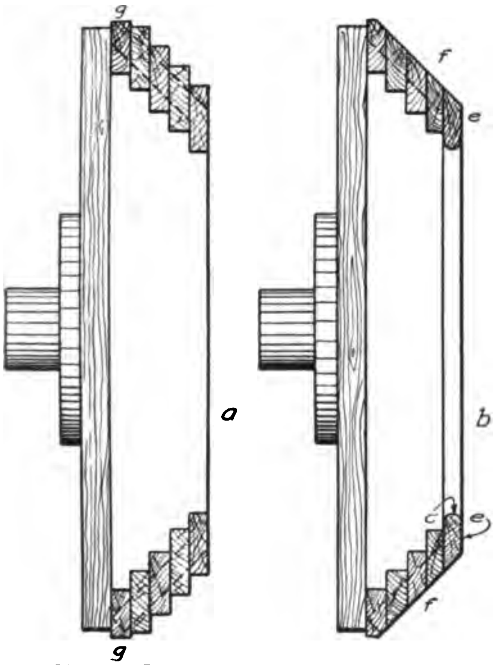


Fig. 261. Large Bevel and Miter Gears Constructed of Built-Up Stock and Turned on Faceplate

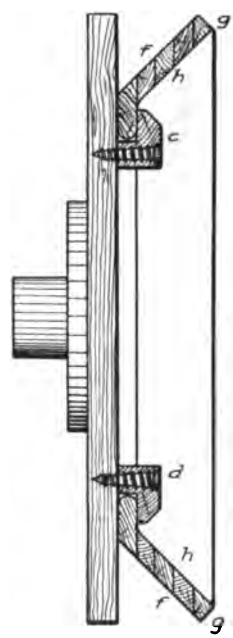


Fig. 262. Section of Miter Gear, Shown Screwed to Faceplate for Turning

section of hub, arm, rim, and tooth. Marking the thickness of segments on this layout will show the diameter dimensions, which can be taken directly from the layout.

Rim. The process of gluing the segments will be the same as used for the pulley rims previously considered—gluing paper between the faceplate and the first layer of segments, and also nailing through the segments into the faceplate, or placing wood screws through the faceplate into the first layer of segments. When a sufficient number of courses have been glued together, including the temporary fitting of the arms, the face *f* and the edge *e* are to be turned to correct angle and diameter. Make a template for the angle shown in Fig. 261, taking the dimensions from the full-size layout. The rib *c*, which will finally be a continuation of the arms, is also turned to

shape and to the thickness of the ends of the arms. The rim will then present the appearance shown at *b*, Fig. 261.

Remove the rim from the faceplate and nail and glue six blocks to the faceplate. Turn these blocks to the inside diameter of the ring *c* and fasten the rim to the faceplate with six clamp pieces, shown at *d*, Fig. 262. In this position the edge *g* and the inside of rim *h* is turned and finished as shown. It is not necessary here to describe the method used in finding the required angles for the face and edges of the rim, but, as in the case of spur-gear teeth, the student should refer to Mechanical Drawing.

Drawing Arms. The arms, partly shown in Fig. 263, are next fitted and fastened to the rim. It is well to glue a small disk on each side of the web of the arms, as shown, which not only strengthens the arms, but serves as a fillet around the hub of the wheel.

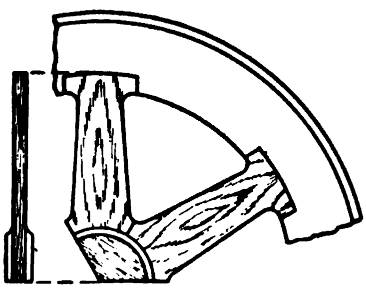


Fig. 263. Part of Arm Pattern for Miter Gear

Loose Pieces. In Fig. 264, the hub *H* and the ribs of the arms *RR* are often made loose so as to lift with the cope, which is of great advantage in molding.

Fitting Teeth. The blocks for the teeth are next fitted in place, either as illustrated in Fig. 264, or in the form of alternate blocks and strips as was shown for the spur gear, Fig. 254. After all the blocks are in place, the wheel must be put in the lathe and turned to the sizes and angles required for laying out the teeth. A sharp line must be drawn on the face of the blocks, while in the lathe, to serve as a guide for the dividers while spacing the teeth.

Use of Centrolinead. To obtain the center lines for the tooth faces after spacing on the blocks, it will be readily seen that the ordinary try-square cannot be used as in the case of the spur gears. A temporary square or centrolinead may be made for this purpose as follows:

Take a piece of hard wood about 6 inches long, 3½ inches wide, and ½ inch in thickness. Dress the two edges perfectly parallel and from the upper edge *a*, Fig. 265, with a try-square and a sharp pointed knife, draw the line *c*, equally distant from each end of *A*,

and at right angles to the edge a. Lay the edge b of A against another board B, of the same thickness, and continue the line c on this board, as shown by the dotted line. With the dividers set on the extended line c on the board B, and with a radius equal to the longest distance of the outside edges of the tooth blocks from the gear center, describe the arc xy on A. Cut the edge b to this arc,

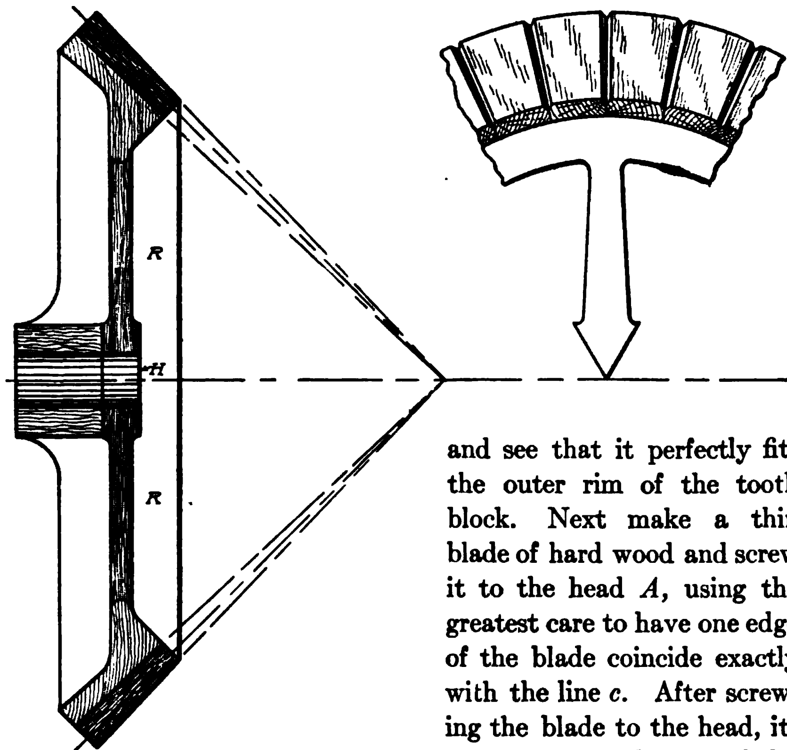


Fig. 264. Section of Miter Gear, Showing Stock Assembled for Teeth

and see that it perfectly fits the outer rim of the tooth block. Next make a thin blade of hard wood and screw it to the head A, using the greatest care to have one edge of the blade coincide exactly with the line c. After screwing the blade to the head, its accuracy may be tested by placing a try-square against the edge a. The result will be as shown in Fig. 266, in which the edge c is radial to the arc xy. This edge will describe the center lines of the teeth radially, as required.

This temporary square can be used, within the limit of its blade, on wheels of larger diameter than that to which it has been fitted, but cannot be used for smaller wheels. For the larger gears the position will be as shown in Fig. 267, which will give the correct

perpendicular if the angles at x and y are carefully made. By using in this way, only a few squares will be needed for a great number of wheels.

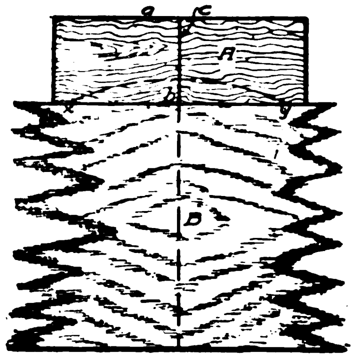
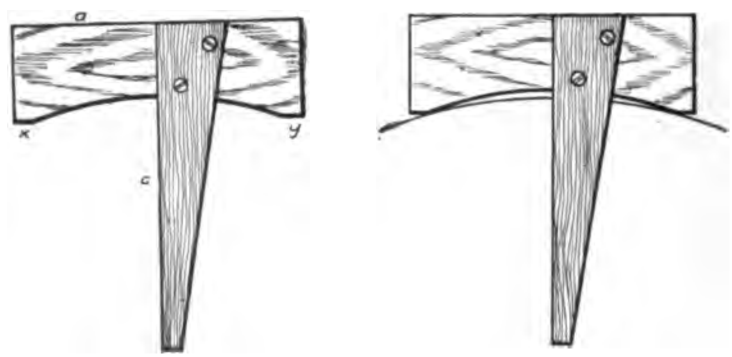


Fig. 265. Construction of Template

Fastening. When the teeth are large, they must be screwed on from the inside of the rim. If small, they should be bradded from the outside or face of the tooth into the rim after the teeth have been shaped and finished.

Templates. Two templates will be necessary for laying out the ends of the teeth, the outer ends being larger than the inner. These templates are made as described for spur gears, and have the outer end bent to fit over the angles of the rim.



Figs. 266 and 267. Templates for Face of Teeth

COLUMNS

Patterns. Cast-iron columns are often ornamented or fluted as shown in the half section of a fluted column in Fig. 268. In all such cases the body of the pattern is made octagonal, as shown by the outline $ABCDE$. The loose pieces forming the flutes are held to the main body by pins that stand at right angles to the line AE. After the sand has been rammed, the body included in the outline $ABCDE$ may be lifted out, [leaving the parts $AabB$, $BbcC$, etc., imbedded in the sand; then, one after another, these latter may be

lifted out. These fluted sections should never be so few in number that they cannot be lifted out without tearing the sand. Eight or twelve sections will be needed.

Other forms of ornamentation are put upon columns in a similar manner. Leaves or flowers are held by pins or in grooves in such a way that the main body of the pattern may be lifted out without disturbing them, and they then may be withdrawn from the sand through the cavity left by the main pattern.

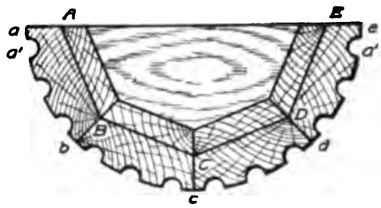


Fig. 268. Section of Ornamental Column Showing Loo.e Pieces Picked-In

Cores. Cores for columns may be made in core boxes as in the case of those for pipe, but where the core is long and straight no core box is needed. The core is usually buit of loam about an iron pipe, as explained in Foundry Work.

Where the core is to follow the lines of the ornamental moldings on the outside of the column, it may be provided with a special core box or better with a sweep, as shown in Fig. 269. This sweep is used to shape the loam core that is to be built up on an iron pipe. Fig. 269 is the outline of the template that is to be used in sweeping the core for the interior of the columns shown in Fig. 270.

Follow Boards. All thin patterns that are likely to suffer distortion from the pressure of the sand, while being rammed up, must be provided with accurately fitting follow boards. These follow


Fig. 269. Strike, for Making Loam Core for Column

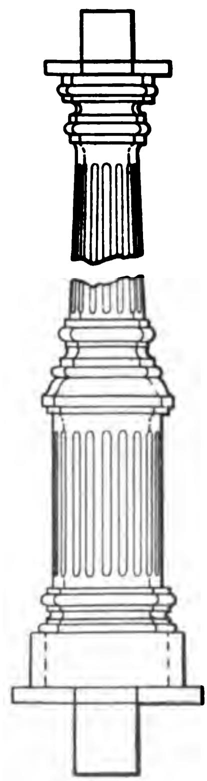


Fig. 270. Completed Column Pattern

boards may be made to fit on either one or other of the sides of the pattern.

When the outlines of the pattern are very irregular, the follow boards are often made of plaster or other composition, which, when dry, is used to support the pattern while the drag is being rammed.

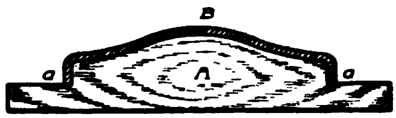
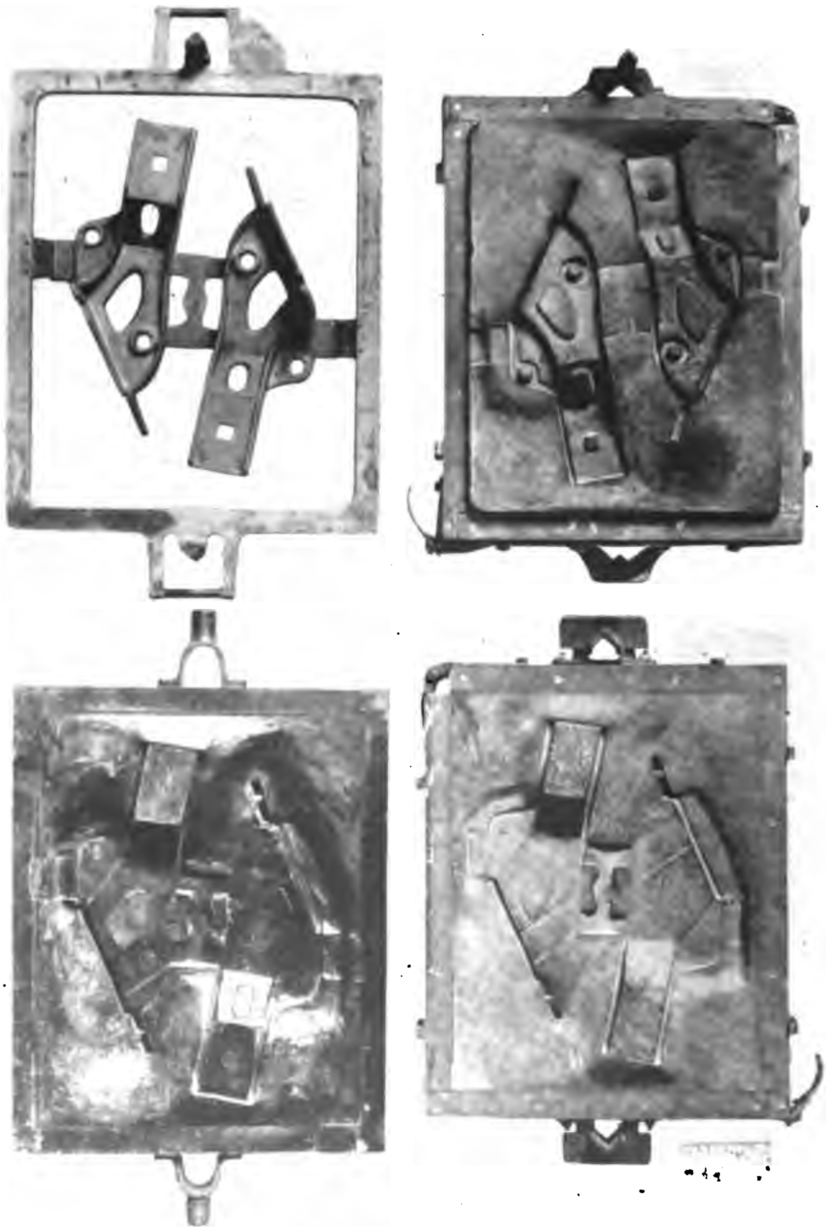


Fig. 271. Follow Board

Fig. 271 represents a section of a railing cap. If the pattern *B* were to be set with the edges *a a* resting upon the molding board and the sand of the drag rammed down upon its upper face, it would be sprung out of shape. To avoid this the follow board *A* is made to exactly fit the under side of the pattern. Then when the sand is rammed, the whole pattern is supported and there will be no distortion. When the cope is rammed, the follow board is removed and the sand of the drag supports the pattern while the cope is being rammed.



PATTERNS MOUNTED IN VIBRATOR FRAME
Upper Left—Patterns in Frame; Upper Right—Drag Half of Mold; Lower Left—Hard Sand Match; Lower Right—Cope Half of Mold
Courtesy of Tabor Manufacturing Company, Philadelphia, Pennsylvania

PATTERN MAKING

PART III

COMPLICATED PATTERN CONSTRUCTION

HAND- AND MACHINE-MOLDED EXAMPLES

HAND-MOLDED HYDRAULIC TURBINE

Conditions. This class of work requires a very clear conception of the principles of pattern making. The working drawings are for the completed casting as usual, Fig. 272, while the several core boxes are designed and constructed by the pattern maker. Extreme accuracy must be exercised, for the slightest variance will be noticed when the cores are assembled, and also in the results of the output and efficiency of the turbine when installed. The type of turbine shown is adapted to fairly high head or fall of the water, relatively small power output, and low speed. The form of the guide vanes and rotor vanes—the latter commonly and erroneously called buckets—shall be furnished by the designer, and a sheet-zinc or brass template should be made to this design. If possible, have the designer check these templates and have them carefully stamped with the diameter and other data, so that they may be readily identified.

In all the illustrations, like letters will denote like parts. Fig. 272 is the working drawing of the guide ring, showing the principal finish dimensions. No attempt will be made to give data for the form of the vanes, but the shape shown will be close enough to that used in practice, for the considerations of the pattern maker. To have it clear just what is being built, it should be understood that the rotor ring is the revolving portion, while the guide ring is stationary, and that water passing through the guide ring from outside to inside continues on through the rotor ring and discharges into and out through its center. The guide ring is bolted to the casing and the rotor ring is bolted to the rotor hub. The casing and hub are not shown.

Durable Core Boxes. The core boxes for the guide vanes are often made of wood, having those parts which are subjected to the

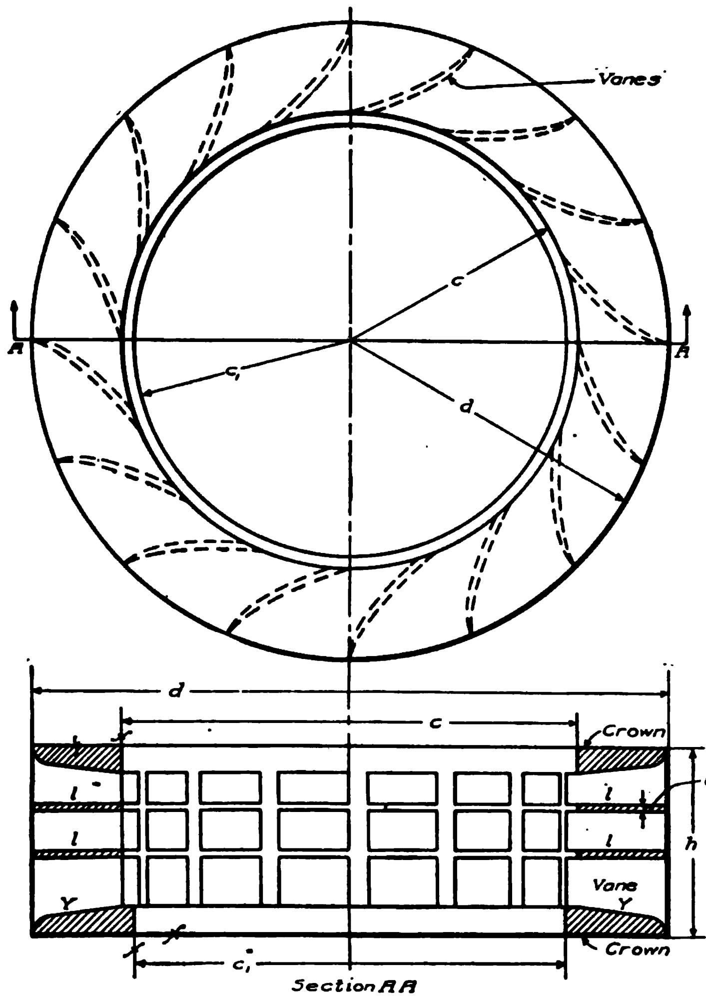


Fig. 272. Plan and Radial Section of Guide Ring

most wear lined with sheet brass, or perhaps hard wood. These boxes are not made of solid glued stock, but are framed together in such a way as to prevent as much as possible of the distortion due to shrinkage. However, in our consideration it is intended to produce a set of core boxes for these castings which may be used

for years. The core boxes for the guide and rotor vanes will be constructed of cast iron, for these parts of a turbine are often required to be replaced, and wood core boxes are liable to become distorted and wear out of shape so as to give unsatisfactory results.

Guide Ring Coring

Guide Vanes. The illustrations and descriptions are for the guide-ring casting; the equipment for the rotor-ring casting being very similar to that for the guide ring except in dimensions. Fig. 273 is a plan view of two cores, set together so that the space between

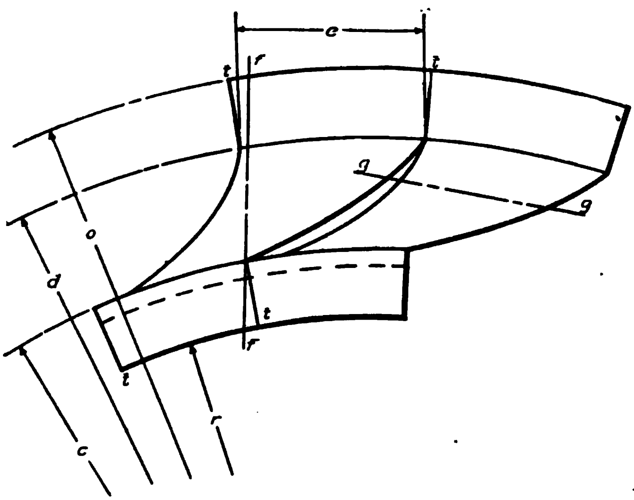


Fig. 273. Top View of Two Cores for Guide Ring

forms the mold for one of the guide vanes. The radius *d* is the outside of the ring casting, including the finish allowance, and *c* is the inside of the casting, including the finish. The difference between the radii *o* and *r* equals the radial width of the dry-sand core. This is also indicated in Fig. 274, where are shown the core box halves. The radial dimensions denoted by the differences between *d* and *o*, and *r* and *c* depend somewhat on the diameter of the ring; for a guide ring with outside diameter of about 5 feet, this radial difference should be 2½ inches each.

Template. On a new sheet of zinc carefully lay out arcs with the radii *o*, *d*, *c*, and *r*, and the form of the face and back of the vane

per data given by the designer. The chord *e* must be carefully spaced to give the proper number of vanes. Multiply the diameter of the outside of the cores by the sine of ½ of the included angles for this chord length. As a dry-sand core swells slightly while it is being dried, this chord *e* should be made a little short of the figured

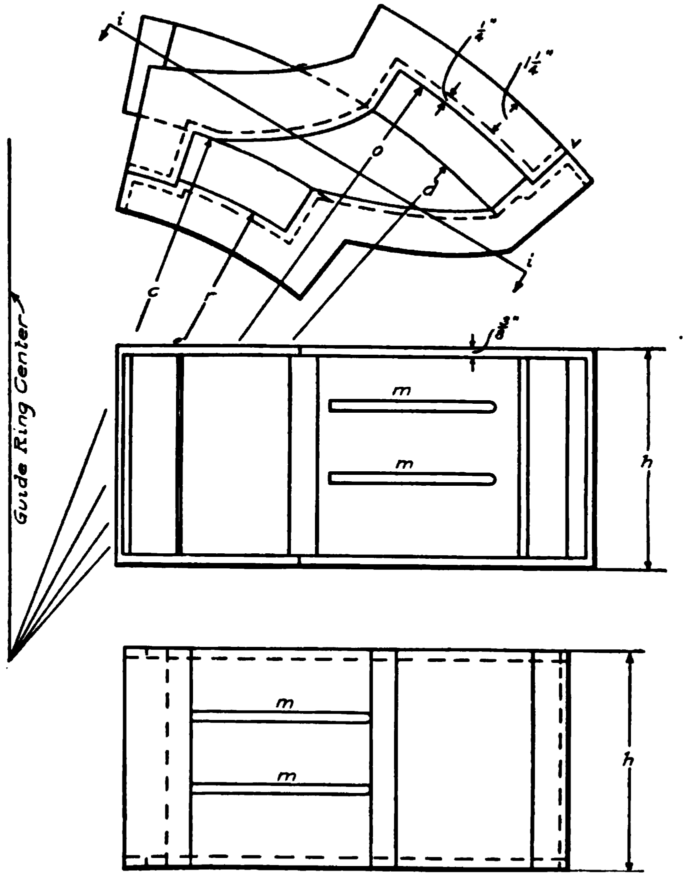


Fig. 274. Plan and Elevations of Iron Core Box

length. Experience is the best teacher as to how much should be allowed for this expansion, different mixtures of core sand, hardness of ramming, and rate of drying, all having effect, and the bottom of a core expanding more than the top, due to settling from its own weight. Make the chord *e* $\frac{1}{32}$ inch short for this casting. Sixteen

vanes are shown in Fig. 272 so as not to appear too complicated, but twice this number would be nearer that used in practice. The wooden pattern for the core box is to be made double shrink—¼ inch per foot—so double shrinkage should be allowed when laying out the form of the zinc template. The form of this template is shown in Fig. 273 by the letters *tttt*, and another template with single shrink of ⅛ inch per foot, should be made for checking the dimensions of the iron core box.

Vane Core Box. *Flanged Sides.* Preliminary to making the durable iron core box, Fig. 275, prepare stock for the flanges for the wooden core box ¾ inch thick, obtaining the form and dimensions

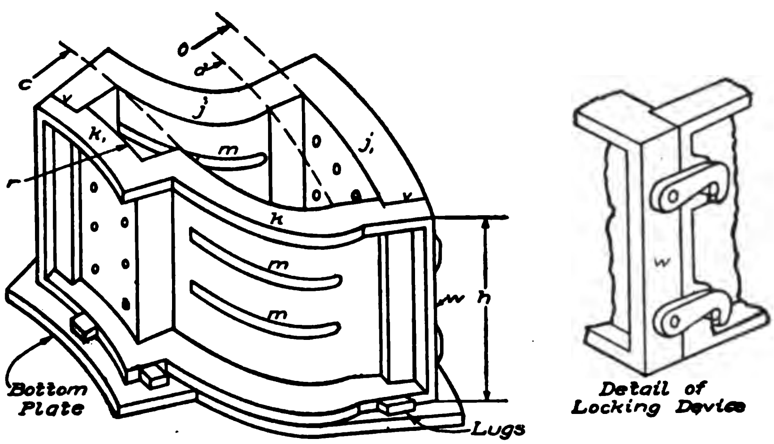


Fig. 275. Diagram of Completed Iron Core Box

from the double-shrink zinc template, and making the inside edge ¼ inch outside of the template so as to run the stock for the outside wall from bottom to top, as shown in Fig. 276. The perspective sketches in Figs. 275 and 276 illustrate the appearance of these flanges, the pieces *j* and *k* being sawed to the full length and the tenons produced with the machine saw. The grain of the stock should be as nearly parallel to the length of each piece as possible.

The layout for these flanges need only be made on one piece of stock. Nail two or more pieces of stock together, as the needs may be, band sawing all from the one layout. In nailing stock together for this purpose, use two slim finish nails and drive them

one at each end—not near each other at the center, and not in the waste stock. These same nails will then hold the pieces firmly together while the edges are being trimmed smooth and true. Should the depth *h* be over 12 inches, an intermediate flange should be made and placed between the openings *m* and *m*. Glue *j* and j_1 together, using care that the angle between them is correct. A slight draft should be made on these flanges, the outside edges being the thinnest.

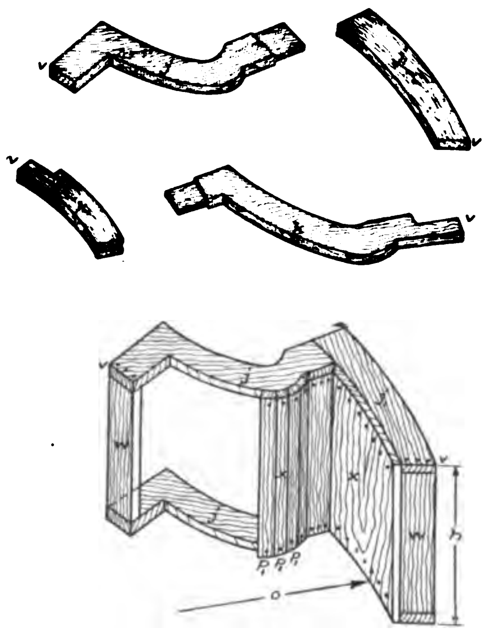


Fig. 276. Flanges and Partially Assembled Rear Half of Core-Box Pattern

With stock for the pieces *w w* dressed to size, the flanges are nailed and glued together, as shown in Fig. 276. All parts should be hand-planed before they are assembled. Always nail each joint in correct location —driving the nails only far enough to locate each piece—before the glue is applied. When the nails are driven through the joint after the glue is applied, the glue acts as a lubricant for a few seconds, causing the parts to slip, and some of the glue will be pressed out of the joint so as to obscure the construction lines, with the result that often a joint will be finally fastened together a little out of position.

Another rule that must be followed by the accurate pattern maker is never to use a lead pencil or a scratch awl for marking center and construction lines; use a thin pointed knife and make sharp deep lines. Pencil lines are too broad, and the awl tears the stock. Center lines should always show on the surface of the completed pattern, but construction lines should not, unless they mark the location of some future alteration or addition. The center lines are necessary for checking the dimensions of the pattern.

Having the flanges assembled, nail and glue the walls x in place. This stock is to be $\frac{1}{4}$ inch thick, with the grain running vertically. Where the radius is short, narrow pieces should be used as shown. The work on the opposite half should be carried

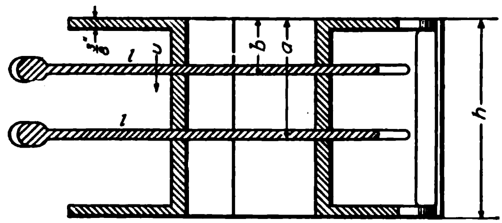


Fig. 277. Vertical Section of Core Box on Line i i, Fig. 274

on at the same time. Smooth the inside of each half and the whole to fit the template.

Slots and Draw Pieces. The slots m m shall be carefully laid out to the dimensions a and b, shown in the vertical section of the core box, Fig. 277. Bore holes at each end, and saw with a thin backless saw. It will be necessary to start the cut with a keyhole saw. The edges should be trimmed with a chisel and have a decided draft to each side, as the slot is molded with a green-sand core. See that there is no back draft at the ends, and to prevent this, the slot should be made shorter than the required width, being filed out in the casting.

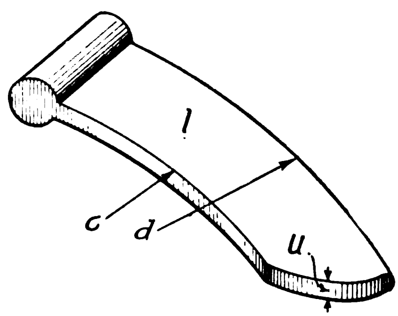


Fig. 278. Draw Pieces for Core Box

A pattern for the draw pieces l and l is to be made as shown in Figs. 274, 277, and 278; the radii c and d being shown in Fig. 272. The thickness is u, and an enlargement at one end is provided to serve as a handle. Two castings from this pattern are required.

Bottom Plate. A cast-iron bottom and top will require a right- and left-hand pattern, illustrated in Fig. 279. Stock should be glued of narrow pieces, say 3 inches wide, with the heart side of

the stock reversed, and should be cut to the form shown in Figs. 275 and 279. The small blocks or lugs are so placed that they center the bottom with the sides. This bottom can be centered with the sides by dowel pins in holes drilled through the flange. However, as the bottom and top should extend outside of the flanges, to provide means for lifting, there will be plenty of room for these lugs.

The piece *y* which forms the mold for the upper and lower crown is glued to the plate, and stock should be removed with carving gouges from the opposite side to prevent as much weight as possible. This piece is sawed to the form of the template and the radii *c* and *d*. The face shall be carved to the bevel and round corner shown in Fig. 272. A radial template of thin wood can be made to show the form of this surface. If the template with its edge coated with blue chalk is passed over this surface, it will indicate the high spots.

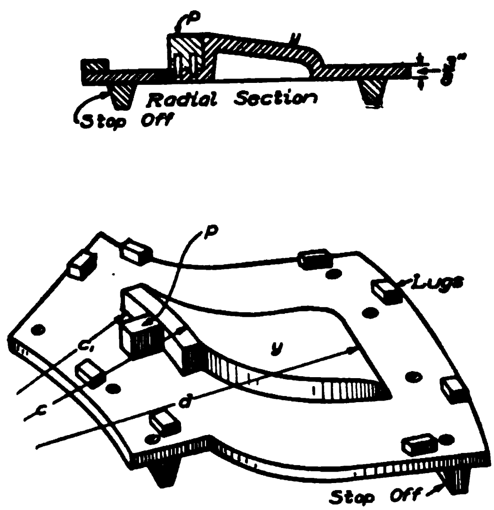


Fig. 279. Bottom of Vane Core Box

These can be reduced with the carving gouges until nearly to dimension, when the surface should be smoothed with one of the flat iron spokeshaves.

Stop-offs, shown in Fig. 279, should be screwed to the outside of these wooden patterns to prevent warping. They should have liberal draft, say about 3 inches to the foot, and should be finished to some color different from the body or core-print portions of the pattern. The imprints of these stop-offs are filled in after the pattern is drawn, and do not come in the casting for the metal core box.

Pouring Gate. The block *p*, Fig. 279, forms a pouring gate and generally is used in four of the cores. It can be made of hard

wood or iron, and is held in place by two small steel dowels. The pattern maker should consult the molder for the dimensions of this gate.

The gate continuation should be made of a dry-sand core,

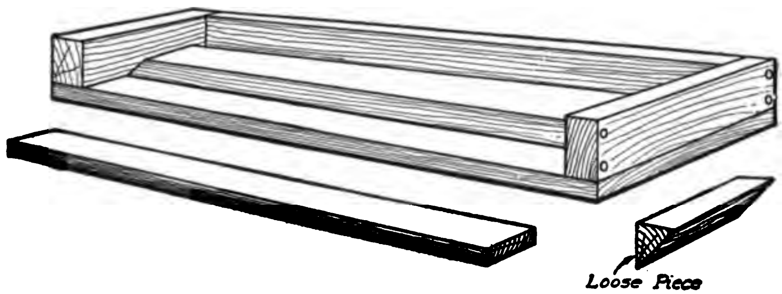


Fig. 280. Perspective View of Core Box for Gate with Side Removed

which is shown in Fig. 286, and the core box for which is illustrated in Figs. 280 and 281.

Core-Box Top. The top of the core box is made to the same dimensions as the bottom, but is made the opposite hand. The gate *p* is to be fitted to both bottom and top.

Use of Core Box. These guide rings are made both for turbines which rotate in a right-hand direction and also for left-hand

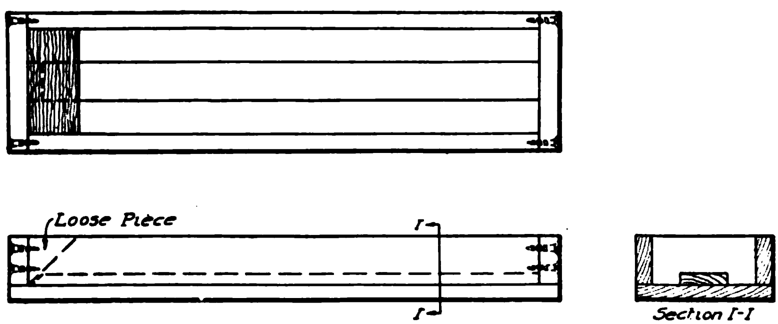


Fig. 281. Details of Core Box for Gate

rotation. The same core box can be used for both; consequently what is the bottom of the core for the right-hand turbine becomes the top of a left-hand turbine.

The hooks for locking the box together, while ramming the core, are iron or soft-steel forgings and can be fitted by the metal-pattern

maker. In ramming the core, the sides are clamped together and placed on the bottom. Core sand is rammed to the underside of the lower draw piece, and is then struck off with the strike shown in Fig. 277. Inserting the draw piece, the ramming goes on and the strike is again used when the upper draw piece is reached. With both draw pieces in place, the box is rammed to the top. Using the strike, it is possible to ram the sand firmly under each draw piece, where it would be rather difficult to ram in any other way. Sand is now cut out at the top nearly to the shape of the top crown, and the top of the core box pressed into place. This top may have to be removed several times until the right amount of sand has been removed. When the top of the core is completed, the space forming the top crown of the ring is filled with green sand, a drying

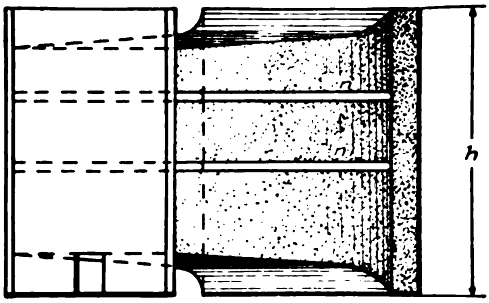


Fig. 282. Elevation of Guide-Ring Core Looking from Ring Center Outward

Fig. 283. Core Box for Bottom Core

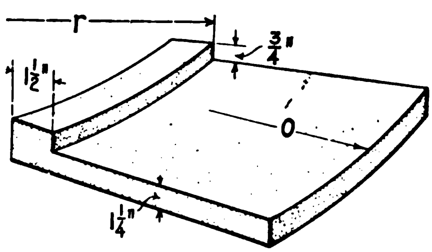


Fig. 284. Details of Bottom Core

plate placed on top and the core box and all are rolled over. The bottom can now be removed and the draw pieces drawn out through the side, forming the mold for the intermediate crowns *ll*, Fig. 272. The sides can now be taken from the core, which appears as in Fig. 282.

Bottom Core. The core box for the bottom core is shown in Fig. 283, and the core in Fig. 284, and in the radial section of the assembled cores, Fig. 286. The number of flat cores to go around should not be the same as the number of vane cores, but enough to give an outside chord length of about 20 inches. The dimensions of this core, shown in Fig. 284, are not arbitrary, and should be made to correspond to the requirements of the weight of the

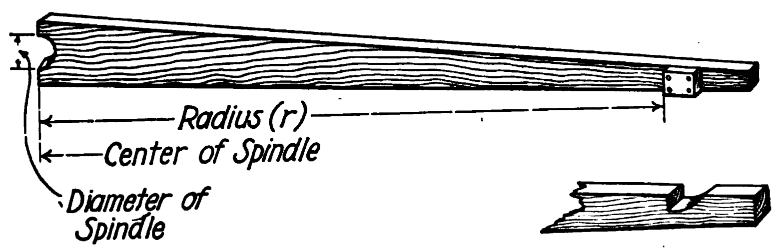


Fig. 285. Gage for Setting Bottom Cores

vane cores. The illustration of the core box shows the construction; the thickness of the bottom should be about $\frac{7}{8}$ inch, and the sides about $1\frac{1}{4}$ inch. The bottom can be made of pine or mahogany, and the sides of mahogany, maple, or birch.

Radial Gage. A measuring stick, Fig. 285, must be provided to locate the bottom cores. The semicircular notch at the inner end shall be the diameter of the spindle, which should be about 3 inches, and a small block should be nailed and glued on, or a notch cut in one edge, at the outer end. The radius *r* should be the same as the inner radius of the vane cores.

Cover Core. The covering core *x*, in Fig. 286, can be made in the core box for the bottom core by fitting a loose piece *z*, as shown in Fig. 283, into the core box to stop off the shoulder.

Molding Process. After bedding the drag flask in the foundry floor, a spindle made of a piece of steel shafting, bolted in the hub of an old pulley, or any other method which will hold the spindle

in a vertical position, is bedded in the sand at the center of the flask. The sand inside the flask is rammed hard and struck off level to form what is called the bed. The spindle must stand vertical to this bed. Place the bottom cores on the bed and set them concentric with the spindle, using the measuring or gage stick, Fig. 285. Upon these cores the vane cores are placed, and the covering cores are placed on top of the vane cores. The spindle then is drawn out and the gate cores set. A portion of the shoulder on the bottom cores will be cut out to complete the gate into the mold, as shown in the assembly, Fig. 286. The sprue is made with a tapering wooden pattern placed in position at the junction of the

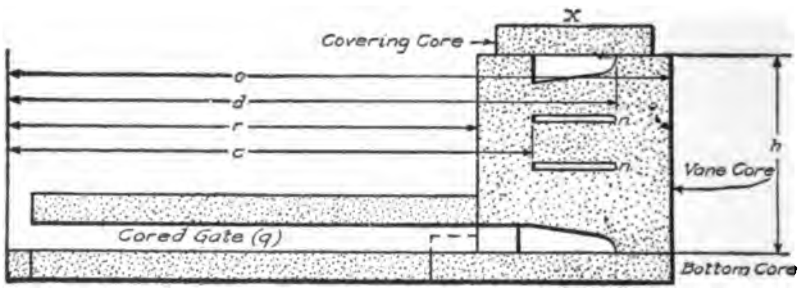


Fig. 286. Radial Section of Guide-Ring Core on Line *ff*, Fig. 273

gate cores. Iron or wood cheek flasks are placed outside of the cores, and rammed full of molding sand. The cores are thus held securely in place and the mold is made without having to turn the drag mold over, which is quite an advantage in heavy work of this class.

MACHINE-MOLDING PRACTICE

Adaptation to Production. The adaptation of patterns to the present-day demands on the foundry for large output of duplicate castings makes it imperative to so arrange the equipment that the largest number of castings per molder-day shall be obtained. This will reduce the labor cost per casting, and where machine molding does not increase the output, it will be possible to employ unskilled workmen, which will lessen the cost. To accomplish this, various arrangements of the patterns have been worked out and the castings all come under the heading of machine molded castings.

Special Study. The concern manufacturing molding machines often contracts to mount on their machines such patterns as are required, and in that case the design and molding operations are worked out by the designing department. However, in many pattern shops the adaptation of the patterns is left wholly to the pattern maker. Now the study of the problems presented is such that the pattern maker soon becomes a specialist, and, if just taking up this work, it will be well to consult the foreman of the foundry, for many questions will arise where the pattern maker would find it difficult to give a practical decision.

Every class of castings calls for a different solution about the equipment that makes the work special. A machine mounted pattern that is a success in one foundry will often be a failure in another. A pattern fitted for machine molding, with the expectation of an order for 1000 castings, probably would not be the same arrangement if the order were for 100,000 castings. Greater expense could be put into the pattern equipment for the larger order, and should be done if the output could be increased. The output per day should be considered, and where a number of small duplicate patterns can be molded in one operation, the flask should not be so large that the operator cannot handle the mold easily.

All in all, this field offers a study of molding and the pattern-making propositions not found in the usual classes of hand-molded patterns. To attempt to offer a complete work on this branch of pattern making would be folly in the extreme. The personal experience of any one expert would require a large amount of space, and the possibilities would only be touched upon.

Increased Uniformity. The changes that have taken place the past few years in the process of machining steel are also evident in the methods of machining castings. In machining large numbers of duplicate castings the machinist resorts to jigs for holding the piece while the work is being completed. It is the case that hand-molded castings will vary in dimensions to some slight amount, due to the slight difference in rapping during molding, which cannot always be kept constant. Patterns are sent first to one foundry and then to another and made today by one molder and tomorrow by another. Even if a machine-molding equipment does not

increase the output, the uniformity of castings and the unskilled labor that can be employed will generally pay for the outlay.

USE OF PATTERN PLATE

Bearing-Cap Pattern. *Shrinkage.* For the use of a pattern plate with the pattern for the ring-oiling ball-and-socket shaft-hanger bearing cap, Figs. 287 and 288, the process of constructing the wooden pattern is identical with that for a hand-molded pattern, except that two shrink allowances are to be made. If the final bearing casting is to be of iron, an allowance of $\frac{1}{10}$ inch or $\frac{1}{8}$ inch per foot will be made for shrinkage, and if the metal pattern is iron, double this amount. With an aluminum pattern, the combined iron and aluminum shrinkage, amounting to $\frac{3}{8}$ inch per foot, must be allowed for.

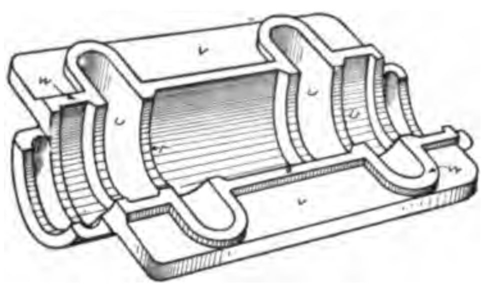


Fig. 287. Cap for Hanger Bearing

Stock Preparation. For best results the stock should be glued of several pieces, as shown in Fig. 289, reversing the heart side of each piece, and using only very dry and sound stock. Dress the glued stock to a parallel thickness and width. The width shall be equal to *d*, the height *c*, and the length *e*. The edges shall be dressed square with the two sides, and longitudinal or transverse center lines are to be laid out on all surfaces.

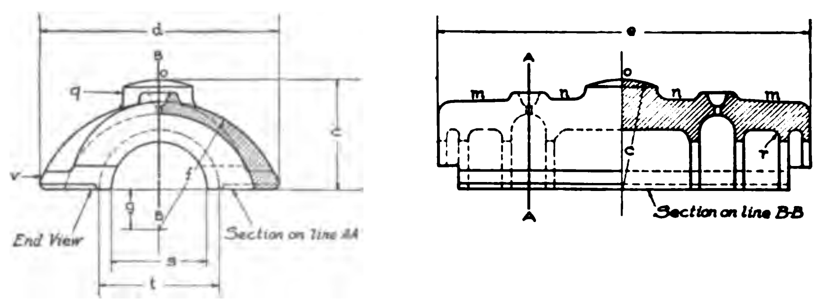


Fig. 288. Working Drawing of Cap for Hanger Bearing

On the working face the complete outline of the pattern should be made as illustrated by the lines *h* in Fig. 289. On one edge

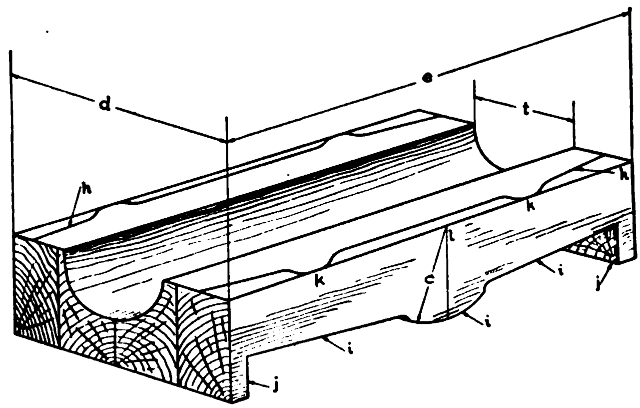


Fig. 289. Partially Completed Stock for Cap Pattern

produce a layout showing the height or thickness of the pattern, as illustrated by the line *i*.

Forming. The semicircular hole is cut out with a core-box plane, to a diameter of *t*, which is larger than the shaft, as this is

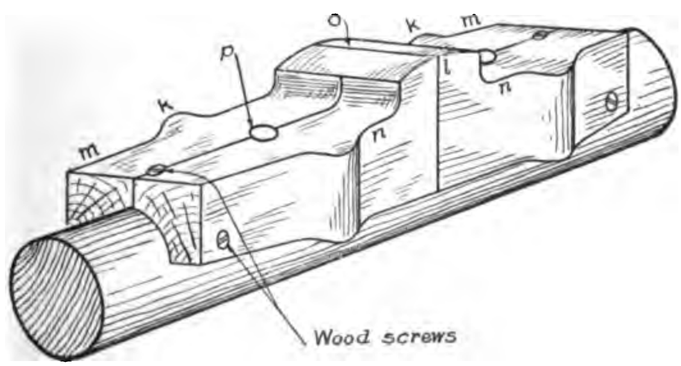


Fig. 290. Cap Pattern Stock Mounted on Wood Arbor Ready to Turn Outside

a babbitted bearing. Band saw to the line *i*, leaving stock at *j j* so that when band sawing to the lines *h h* the top surface or working face of the stock will be kept parallel to the table. The stock at *j* may be cut off with a chisel after the band sawing is completed.

Prepare an arbor and fasten the pattern to it, as illustrated in Fig. 290, with six wooden screws. The pattern may now be put into the lathe, and all parts that are concentric with the arbor *mm*, *nn*, and *l*, may be turned. The lathe should be run at its slowest speed and the turning done with a narrow square-nose chisel. The parts *kk*, which are over the recess for the oil rings, should not be turned. The surfaces *m m* and *n n* can be worked to size by trimming to a template, but the suggested method of trimming will work out very well and produce accurate results. The stock at *l* is to be cut down to the diameter of the pattern at *n*, and at *o*, where the center lines which were made on the squared stock intersect, the center of the boss *q*, Fig. 288, should be found.

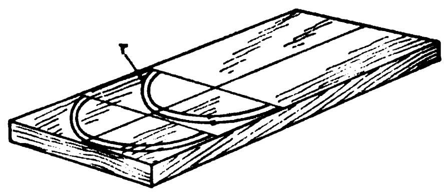


Fig. 291. Preparing Stock for Babbitt Ledges

The babbitt ledges *r*, Figs. 287 and 288, are semicircular rings band sawed from stock of the required thickness, Fig. 291, and the grain of which should be as illustrated. This gives the greatest strength to these parts after they are nailed and glued in place. One small finish nail at each end will be all the nailing required, and the inner diameter will be smoothed on a sandpaper roll. The flanges *vv*, Figs. 287 and 288, are thin strips of stock glued into a rabbet sawed after the turning is completed, and this flange is cut out so as to leave the rim *w*. The oil cups are turned and fitted into the holes *p*, Fig. 290. The recesses *uu*, Fig. 287, are carved with gouges, and the form determined by the use of a template. A little blue chalk on the template will indicate where the stock is to be removed to obtain the correct form.

Making Pattern Plate. The equipment that the molder will require to mold this pattern plate will be a mold board, a pattern for the plate, and four strips of wood to nail to the parting edge of the wood flask.

Pattern Board. The pattern board, an illustration of which is shown in Fig. 292, should be made of pattern stock. Upon locating the pattern, fit and nail the pieces *x x* in place. In the section view, Fig. 293, the form of these pieces is shown more clearly. They form the coped parting, which in hand-molding is cut out by hand,

or is formed by a sand or a plaster match. The ribs *w w* should be fitted into the mold board so that the flange *v* will rest upon the mold board.

Plate Frame. The pattern for the plate is an open frame about ½ inch thick. The opening should be large enough to fit

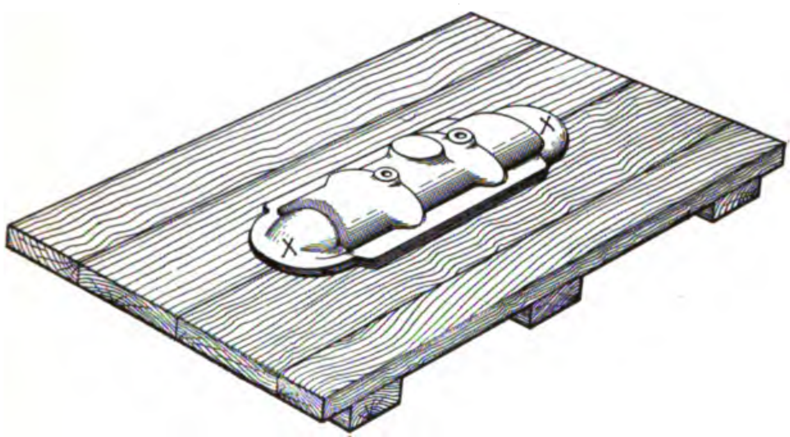


Fig. 292. Pattern Board

over the pattern and the parts of the mold board marked *x x*. The extension at each end should be large enough for the flask pinholes, and also serve as handles. The other portions of the plate pattern should not be larger than the flask.

Molding Metal Pattern and Plate. After ramming the drag mold, it is turned over onto a bottom board, and the pattern board

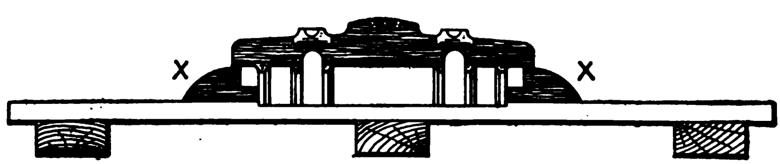


Fig. 293. Section of Pattern Board

removed, leaving the cap pattern in the mold. The cope mold then is rammed and removed, following which the plate pattern is placed on the parting, and strips of wood the same thickness as the plate pattern are nailed to the edges of the flask. The drag mold at this stage has the appearance illustrated in Fig. 294.

Molding sand is now rammed into the space between the plate pattern and the flask, forming a new parting ¼ inch above the parting

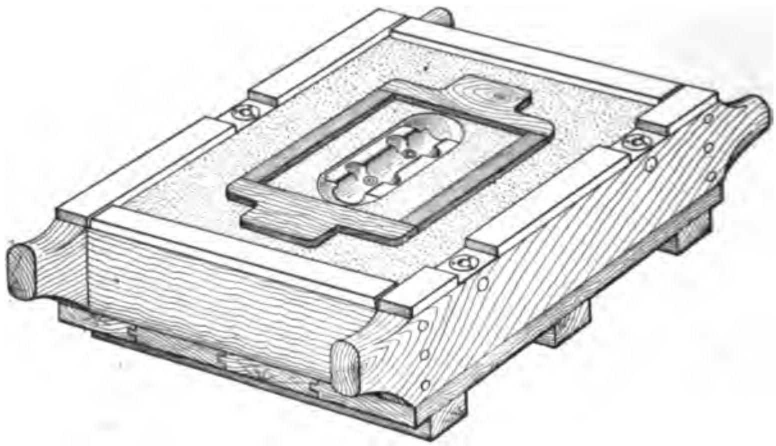


Fig. 294. Drag Mold of Cap for Hanger

made by the pattern board. The cap and plate pattern then are removed and the gates cut.

Closing the cope forms a mold that will produce a pattern plate,

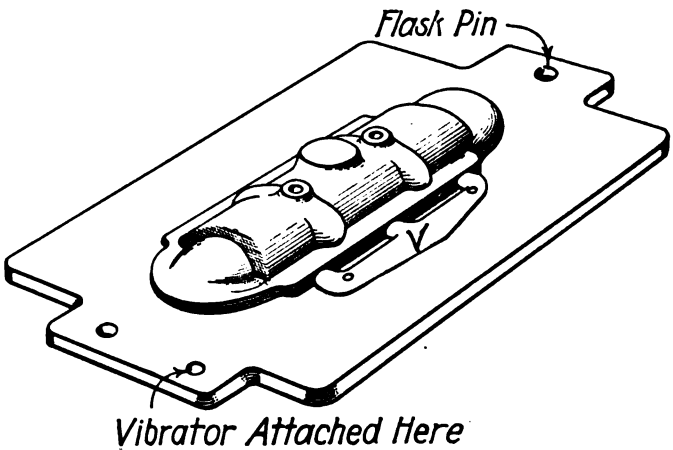


Fig. 295. Completed Plate Pattern

an illustration of which is shown in Fig. 295, and on the reverse side of which will be the opposite side of the cap pattern.

Use of Steel Frame. A system used in some foundries is to have a steel frame for the plate pattern, and, leaving this frame in the mold, cast the pattern and the balance of the plate of aluminum, or some special alloy. This process produces a lighter weight plate and it is intended to melt the pattern out of these steel frames in case the pattern becomes obsolete.

Gate. The pattern for the gate illustrated in Fig. 295, at *y*, may be fastened to the pattern board and cast on the plate, or cast of brass separately and fastened to the plate with two machine screws. This last method allows the gate to be readily removed and altered should a change become necessary.

STRIPPING DRAW-PLATE MACHINE

Flange-Coupling Pattern for Hand Molding. In Fig. 296 is illustrated one half of a flange coupling such as is commonly used on mill shafting. Fig. 297 illustrates a radial section view of a pattern for hand-molding this coupling.

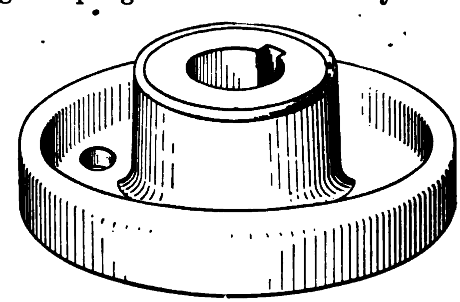


Fig. 296. One-Half of Complete Flange Coupling

Wooden Construction. The web *c* is to be made of glued and splined segments, as recommended for the web of the disk crank in Part II, Pattern Making. A shoulder is turned at the edge of the web to receive the rim, which is built of several layers of segments, the whole being turned on a face-plate. The hub *d* and core prints *e* and *f* are to be made loose. The hub stock will have a 1-inch hole through its center and be turned on a hard-wood or steel arbor. A rabbet is turned at one end, and five or six segments fitted, glued, and nailed into this rabbet to form the stock for the fillet. The hub should have a normal draft—⅛ inch per foot—and a small chamfer or rounded edge on its outer end. The grain of the stock should be parallel to the axis of the hub, whether the stock is made of glued stock or not. The dowel pin *m* should be glued in the hub. Having the hub and core prints loose allows the coupling to be adapted to several diameters of shaft. This requirement occurs when

an increase or reduction of the diameter of a line of shafting is made.

Equipment for Machine Use. It is now desired to construct a molding machine, Fig. 298, with as little expense and delay as possible, whereby a machine molder may produce the casting. The principle used will be a hand roll over stripping-plate process. Figs. 298, 299, 300, and 301 are used to show the equipment requirements, and like letters represent like parts in all figures.

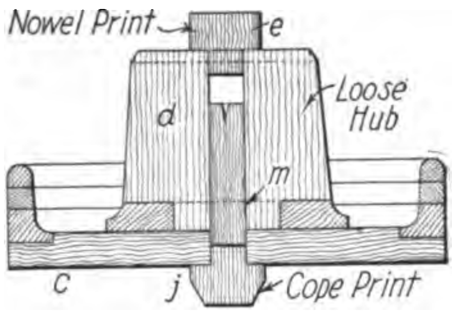


Fig. 297. Section of Hand-Molded Pattern—Loose Hub and Prints

Fig. 299 illustrates a section of the completed machine, on a center line through the flask pins *i i*.

Pattern. The only alteration in the pattern for the flange and web of the couplings will be in the thickness of the web *c*, which must be thick enough to reach through the stripping plate *b* and is to be fastened to the draw plate *a* with three or four flat-head wooden screws. Follow the process already established when making the web, flange, and hub. The hub shall be made loose, and the core prints also, unless the diameter of the cored hole is standard to the hub, when it will be best to make the nowel core print a part of the hub.

Stripping Plate. The stripping plate, Figs. 298 and 299, at *b*, and the core plate, Fig. 298, at *n*, are alike in size. The width should not be greater than the flask, Fig. 301, so that what sand falls over the outside of the flask should fall to the floor. The length, however, should extend beyond the flask far enough to include the flask pins *i*. The stock for these plates is to be about 1⅜ inches thick, and had better be made of narrow strips of stock glued together, with the heart side reversed on alternate pieces so as to prevent warping. The stock should be dry, and have a heavy spline glued in each end, as shown.

Draw Plate. The draw plate should be about the same length and thickness as the stripping plate. The width may be somewhat

less than the stripping plate, but not less than the diameter of the pattern, and not so as to cause the outfit to tip during the ramming of the mold. This plate is not splined at the ends, but heavy cleats are glued and screwed in place, as shown in Figs. 298 and

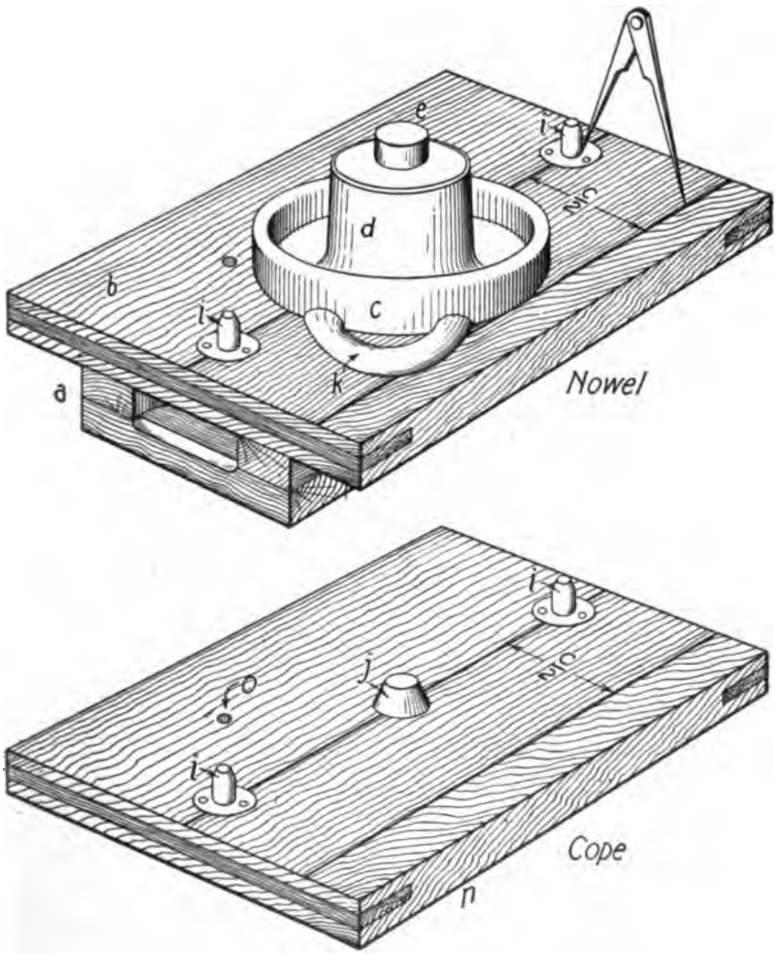


Fig. 298. Simple Form of Molding Machine which Embodies Stripping-Plate and Turn-Over Ideas

299, first cutting out stock at the ends of the plate to form hand holes.

Assembling. On both the stripping and draw plates lay out a center line for the location of the pattern and the flask pins, and

also a checking line parallel to this center line, spaced off exactly one-half of the diameter of the flange of the pattern, $\frac{c}{2}$. After establishing the location of the pattern and flask pins, the 1-inch hole can be bored in the cope plate, and the hole in the stripping plate for the flange *c* can be carefully sawed with a jig saw or keyhole saw. This hole should be fitted over the pattern by blue-chalking the outside of the flange and trimming the stripping-plate stock where the chalk shows. This hole will have to be about $\frac{1}{32}$ inch larger in diameter than the pattern so there will not be any binding when the pattern is drawn through the stripping plate. The stock

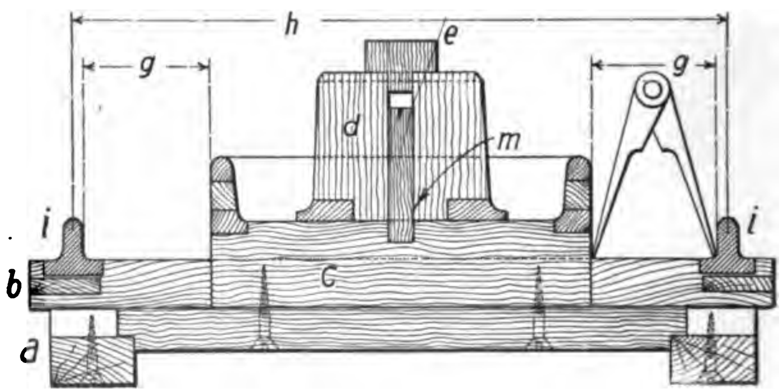


Fig. 209. Section through Center of Nowel Mold Machine

is bound to swell to some extent, but a small amount of sand getting between pattern and stripping plate will grind out the stock, so there will be little trouble from this source.

Flask Connection. The flask pins *i* are to be made of cast iron or machine steel. The diameter of the pin is to be about $\frac{3}{4}$ inch, and the flange about 2 inches in diameter and $\frac{3}{8}$ inch thick. The diameter of the pin should be parallel, to a height of about $\frac{1}{2}$ inch, and slightly tapered above this point to a total height of about $1\frac{1}{4}$ inches. The flange should be drilled and counterbored for three flat-head wooden screws, or, better yet, tapped for three flat-head stove bolts, which will be passed up through the plate stock. Counterbore holes in the stripping plate and cope plate, for the flanges of these flask pins, being very careful to center these holes accurately.

Fasten the pattern to the draw plate and place the stripping plate in position. Test the dimensions *gg* with inside calipers, as shown in Fig. 299 also check the dimension *h* with the flask-

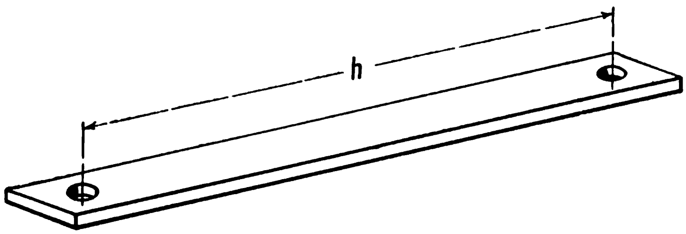


Fig. 300. Jig for Locating Centers of Flask Pins on Machines

pin jig shown in Fig. 300. This jig is made of flat steel stock, and the holes are drilled with the same jig which is used for drilling the holes in the flask, Fig. 301. Test the distance from the checking line to the flask pins with hermaphrodite calipers, as shown in

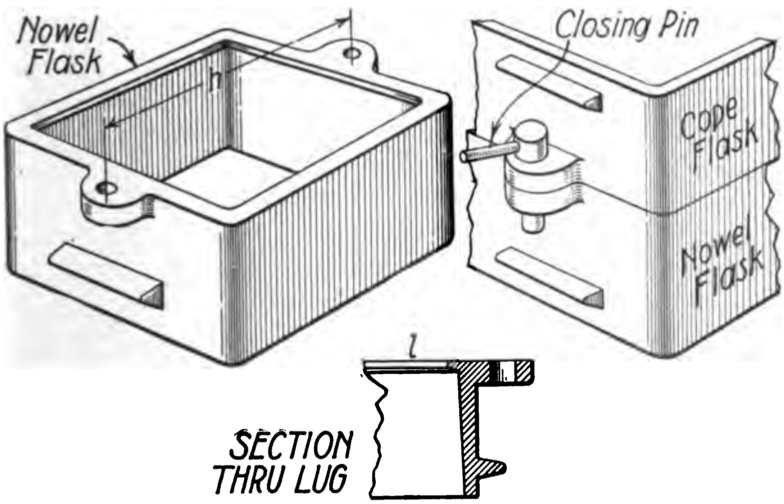


Fig. 301. Sketches of Cast-Iron Flask Showing Closing Pins

Fig. 298. Test the location of the cope core print in the same manner. The flask pins can be adjusted by loosening the screws and driving a wedge between the pin and the plate stock so as to force the pin into the correct location. The alignment of the pattern

and the flask pins should be such that the mold can be closed with the cope either way around; however, the location of the sprue will determine this.

Gate. The pattern for the gate *k*, Fig. 298, is crescent shaped and is nailed to the stripping plate. The pattern maker had better consult the experienced molder for the dimensions of this gate. A small hole should be drilled in the cope plate at *o*, Fig. 298, so as to locate the sprue opposite the center of the gate pattern.

Identification Marks. Pattern numbers, size of coupling, or other means of identification should be marked on each end of the stripping plate. In this location they can readily be seen when the patterns are on the storage rack. Do not place these marks on the ends of the draw plate, as the pattern is rapped by striking the ends of the draw plate before the pattern is drawn. Closing pins, Fig. 301, are used while closing the mold, and these are then to be removed.

Parallel Drawing Device

Typical Deep-Draw Work. When the pattern, like the spur gear illustrated in Fig. 302, has considerable depth of draw *d*, there is liability of one end of the draw board being lifted ahead of the other, which will cant the pattern and loosen the sand between the teeth of the pattern, making it impossible to obtain a perfect casting. With the parallel device shown, the draw will be perfectly true and very delicate molds can be made. It is not intended that patterns mounted in this manner should compete for accuracy with an all metal stripping-plate machine, but its ease of handling and roll over suggests its use for many castings frequently mounted on the stripping-plate machine.

Spur-Gear Pattern. The gear pattern is to be made of mahogany —the stock glued to obtain the required dimensions, and having the grain parallel to the axis. Band saw nearly to diameter, bore a 1-inch hole through it at the center, and turn on an arbor. In the assembly, Fig. 303, the length *d* shall be the sum of the face of the gear and thickness of the stripping plate. Have the teeth cut in a gear cutter. This is the same machine used to cut the teeth of metal gears, and commercial gear cutters generally have one

of their machines adapted to this work. The spindle upon which the milling cutter is mounted is run at a speed that will insure

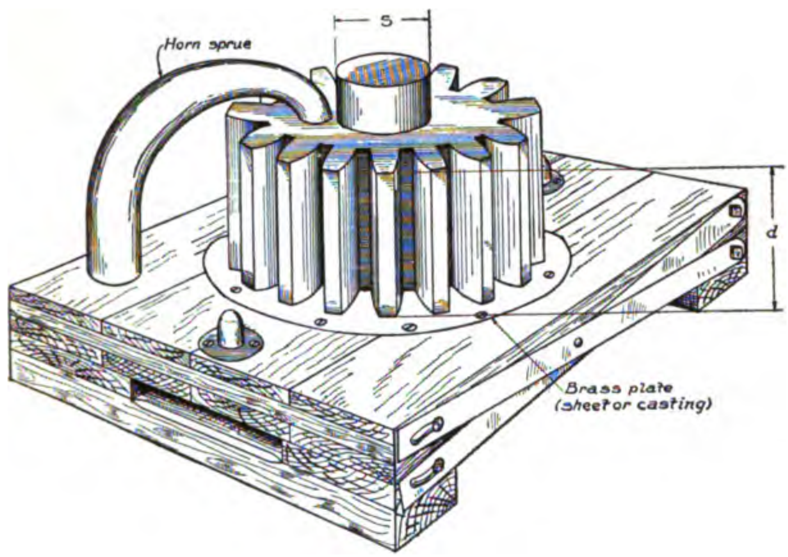


Fig. 302. Draw Plate for Spur-Gear Casting

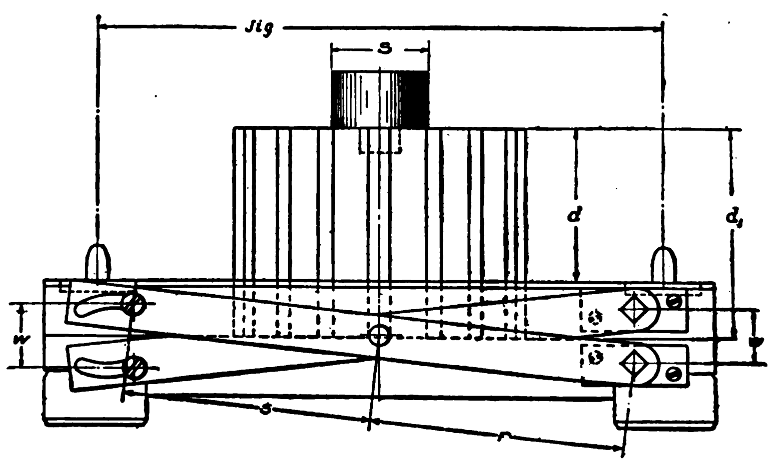


Fig. 303. Elevation of Spur Gear and Draw Plate

smooth work, and a single cutter, called a fly cutter, is fitted to the spindle in place of the milling cutter.

Stripping Plate and Draw Board. The stock for the stripping plate and draw board may be prepared while waiting for the gear pattern. These are to be made of glued stock, splined and cleated the same as in connection with the flange coupling. While not shown, a cope plate shall be made which will be similar to the cope plate for the flange coupling illustrated in Fig. 298. This should be made along with the drag machine. At *h*, in Fig. 304, bore $\frac{5}{8}$-inch holes through both the stripping plate and the draw board. Mount the stripping plate on a faceplate, using care to have the center of the stripping plate and lathe concentric, and turn

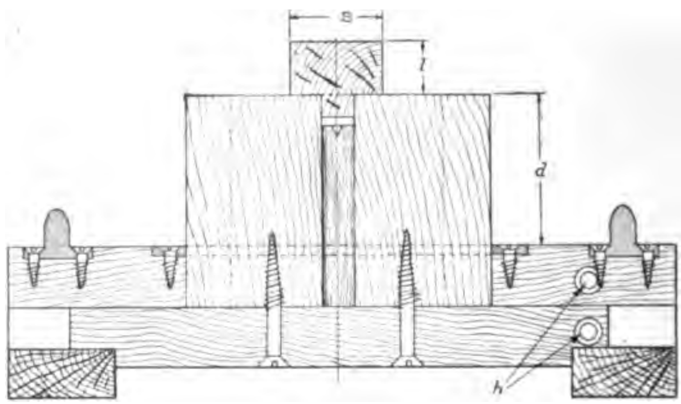


Fig. 304. Section Showing Loose Nowel Core Print

a hole with a diameter equal to the bottom of the gear teeth; also chuck a recess for the brass wear plate if one is used. Machines have been made without this brass plate, but better results can be obtained with it. It may be cut from sheet brass or a casting may be used.

Metal Parts. If a brass plate is used on the stripping plate, the projections which extend into the tooth space should be carefully filed to pass over the pattern easily. Mark the stripping plate to this form and jig-saw it. After fastening the brass plate with several flat-head wooden screws, the hole is to be trimmed so that the pattern will not bind.

The metal pattern maker or a machinist can furnish the metal parts, or if necessary tools are at hand, the pattern maker will not find much difficulty in making them. The flask pins, however,

should be machine turned all over and made duplicate, for, in case of breaking, the labor of replacing will be very much lessened if the pin can be replaced without changing the alignment of the pattern.

Parallel Device. For the side arms of the parallel device, Fig. 306, the stock should be black iron, $1\frac{1}{2}$ inches long by $\frac{1}{4}$ inch, and the length 1 or 2 inches less than the length of the draw board. Make a full-size layout of the motion of the parallel device as

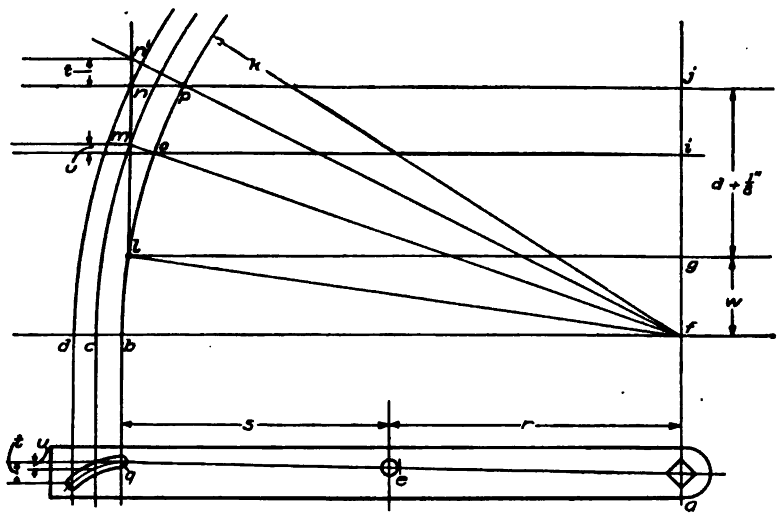


Fig. 305. Layout for Side Arm of Parallel Motion Device

illustrated in Fig. 305. The radius *r* and the dimension *s* must be the same.

Side Arms. From points *a*, *e*, and *q*, project vertical lines *aj* and *qb*. Make all straight lines with a knife point. With *f* for a center, scribe arc *blop* with radius *k*, which is the sum of *r* and *s*. Locate above *f* the point *g* with dimension *w*, and point *j* with dimension $d+\frac{1}{8}$ inch. Dimension *w* is as in Fig. 303, and the $\frac{1}{8}$ inch added to *d* is to insure drawing the pattern clear of the mold. Point *i* is to be located approximately $\frac{3}{4}$ of *d* above *g*. These points *g*, *i*, and *j* are to be projected on vertical line *ln*. Through the intersections of these horizontal projections with arc *bp* at *o* and *p*, lay out radial lines centering at *f*, and extend these lines to intersect line *ln* at *m* and *n*.

Project points *b*, *c*, and *d* to the plan of the side arm, and transfer dimensions *t* and *u* to intersect these lines, giving three points upon which to lay out a curve which will be the center line of the slot. Lay out these centers on one piece of stock, and, clamping the four pieces together, drill out at one time. The hole at *e* will be for a $\frac{5}{16}$-inch rivet, and the holes drilled to form the slot at *q* will be the same diameter as a No. 16 screw. These screws over which the slot slides should be round-head, No. 16 wire, and about $2\frac{1}{2}$ inches long.

Cross Rods. The rods *v*, Fig. 306, which connect the opposite sides are to be $\frac{5}{8}$ inch in diameter, and the ends are to be filed to a

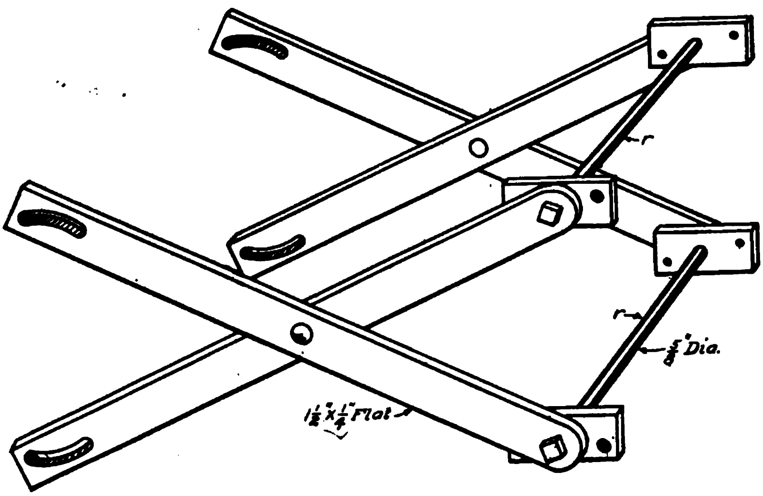


Fig. 306. Details of Parallel Motion Device

square, and a $\frac{15}{32}$-inch hole drilled at *a*, Fig. 305, will be filed square to fit these squared ends. Two side arms are to be riveted together at *e*, Fig. 305, reversing the slots, as shown in Fig. 306, and the $\frac{5}{8}$-inch rods riveted to one pair of side arms; the other pair will be riveted after passing the rods through the stripping plate and draw board.

Short pieces of flat iron, of the same section as the side arms, are furnished with a $\frac{5}{8}$-inch hole at center, and a hole near each end countersunk for a flat-head wood screw, as illustrated in Fig. 306.

Assembly. Assemble the device on the wooden plates. Fasten the bearing plates in the correct location, and, having the draw

board and stripping plate held tightly together, insert the round-head screws in the slots. Try the lift of the draw board, Fig. 307, and, if not equal to $d+\frac{1}{8}$ inch, lengthen the slot to obtain this dimension. All parts should have three or four coats of a shellac finish before assembly. Fasten the pattern to the draw board with three

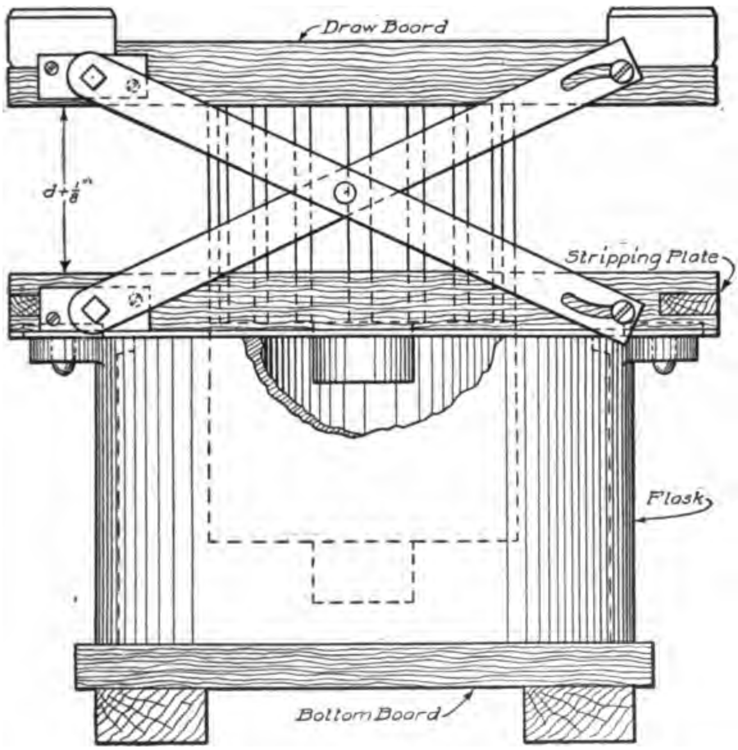


Fig. 307. Draw Plate Turned over and Pattern Drawn; Flask and Bottom Board Also Shown. A further Lift of Drawboard Removes Machine from Mold

or four wooden screws. The flask pins should be located to fit the flask-pin gage, as illustrated in Fig. 303. The mold board for the cope mold should have a 1-inch hole at its center to receive the dowel of the cope core print and a hole for marking the location of the sprue.

Horn-Sprue Gate. The horn-sprue gate should be made of hard wood or metal and should be furnished by the pattern maker. The dimensions should be suggested by the molder, and the dimen-

sions of the flask used should be selected so as to provide room for this gate. The gate should be round in section, and gradually taper from the parting of the flask to the pattern. The inner and outer sides should be true circles so that it can be drawn out endwise. A steel pin is to be fitted in each end of the gate pattern and a hole drilled in the stripping plate and pattern to locate the gate. The sprue in the cope mold must be located so as to match the gate in the drag.

STRIPPING-PLATE HAND-RAMMED MOLDING MACHINE

Hand-Molding Conditions. Before taking up the design and construction of the parts required to adapt the patterns to machine

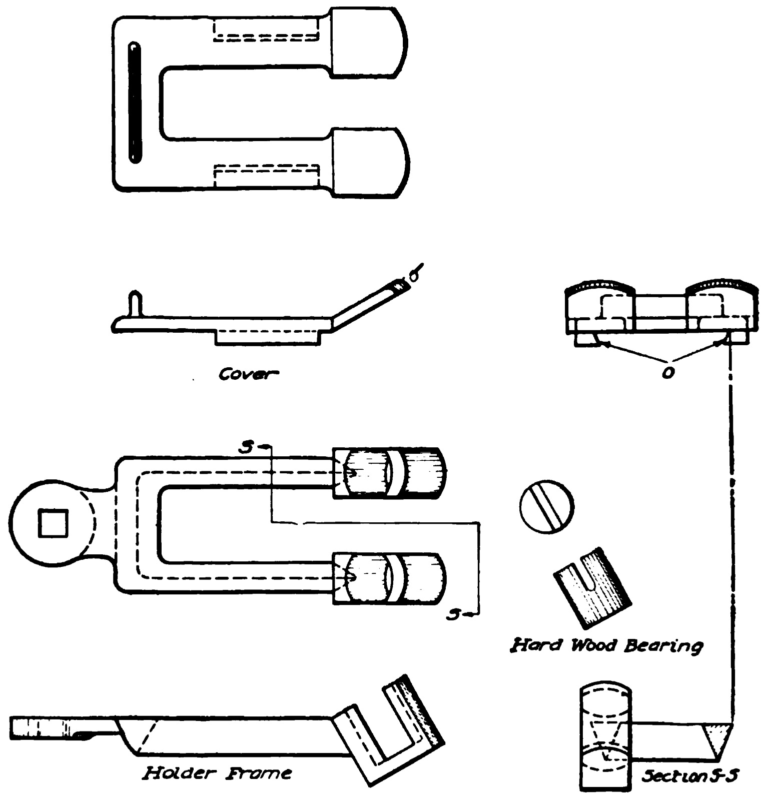


Fig. 308. Working Drawing of Holder Frame that Requires Side Draw

molding, the conditions presented by the hand-molded patterns may be briefly considered. The working drawing, without dimen-

sions, of a holder frame is illustrated in Fig. 308; and in Fig. 309 is a view of the iron-gated patterns. The cover is designed to pass

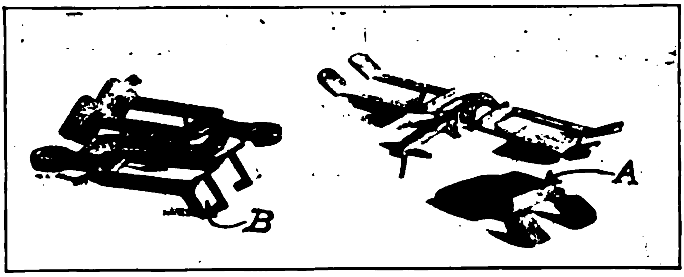


Fig. 309. Original Gated Patterns, Showing First Attempt to Increase Production. They Require Dry-Sand Core for Each Casting. With Machine-Mounted Patterns, Entire Mold Is Made in Green Sand

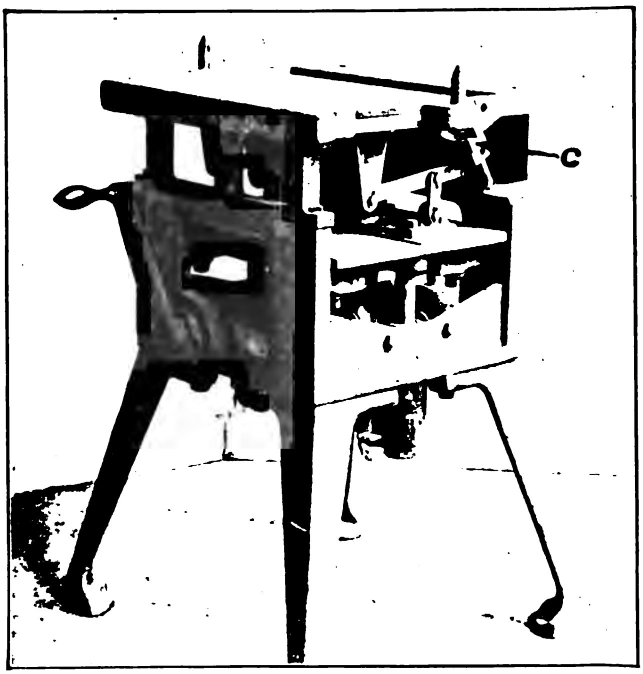


Fig. 310. Nowel or Drag Stripping-Plate Hand-Rammed Molding Machine

endwise onto the holder frame, as indicated in Fig. 308, the bevel on the inside of the lugs *o* being molded with a dry-sand core, and the round recesses in the holder also being molded with a dry-sand

core. The least imperfection to these dry-sand cores means that considerable fitting has to be done to get the parts assembled. With

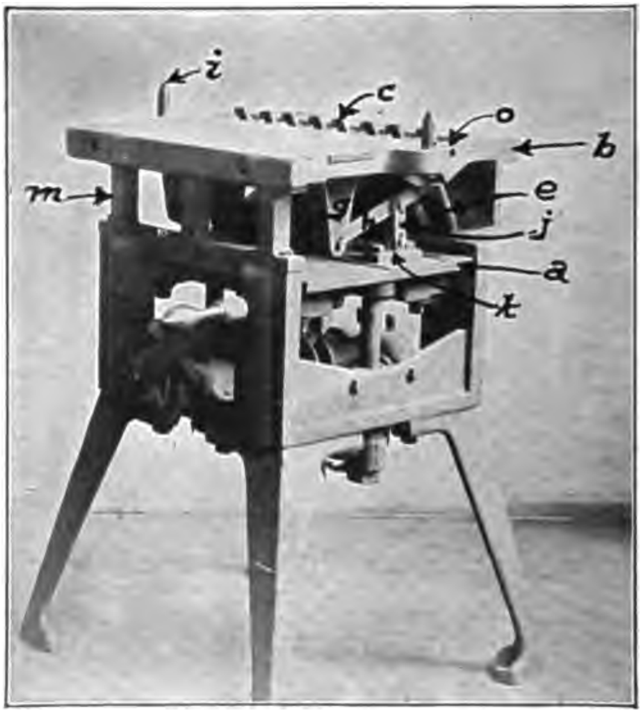


Fig. 311. Drag Machine with Pattern in Position to Make Mold

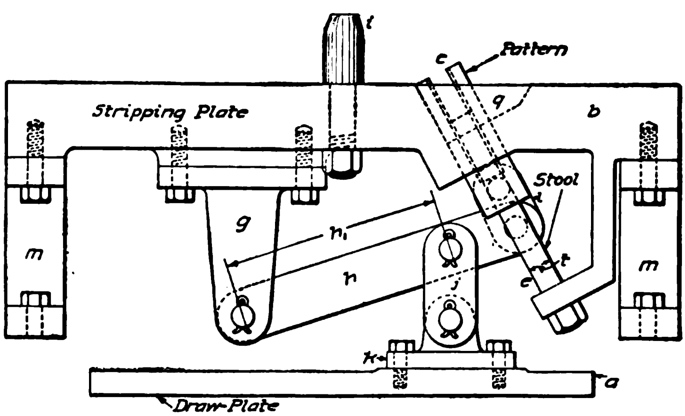


Fig. 312. End Elevation of Pattern Equipment for Reid Hand-Rammed Stripping-Plate Machine

the machine-molded castings, the castings and the hard-wood bearings are literally thrown together.

Molding Machine. In Fig. 310 is illustrated the drag machine, and in Fig. 311, the machine with the pattern in position for molding. An end view of the stripping plate, draw plate, and assembled mechanism of the drag machine is illustrated in Fig. 312, and Fig. 313 is a section through the center of one pattern. This machine is fitted to make four molds which are all gated to one sprue. The mechanism unit is duplicated for each pattern.

The proposition with this drag machine is to draw the pattern at an angle of about 30 degrees from the vertical, and therefore

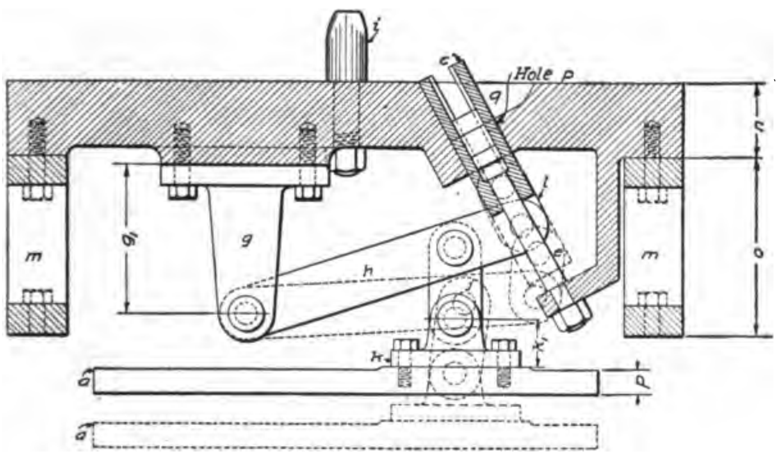


Fig. 313. Section Elevation through One Pattern; Dotted Lines Show Position of Parts with Pattern Drawn

the pattern cannot be bolted directly to the draw plate *a*. To obtain space beneath the stripping plate to install the mechanism spacers are interposed between the top of the machine frame and the underside of the stripping plate, as shown at *m* and *m*. In Fig. 313 the pattern is illustrated in its raised position, and the dotted lines illustrate the position of the draw plate and levers when the pattern has been drawn.

Stripping Plate. A perspective sketch of the stripping plate is illustrated in Fig. 314, part of the casting having been broken away to illustrate the position of the holes through which the pattern is drawn, and Fig. 315 is a sketch of the pattern for the stripping

plate. Small blocks o_1 of cast iron or steel are to be fastened at each end of the depression after the machine planing is completed.

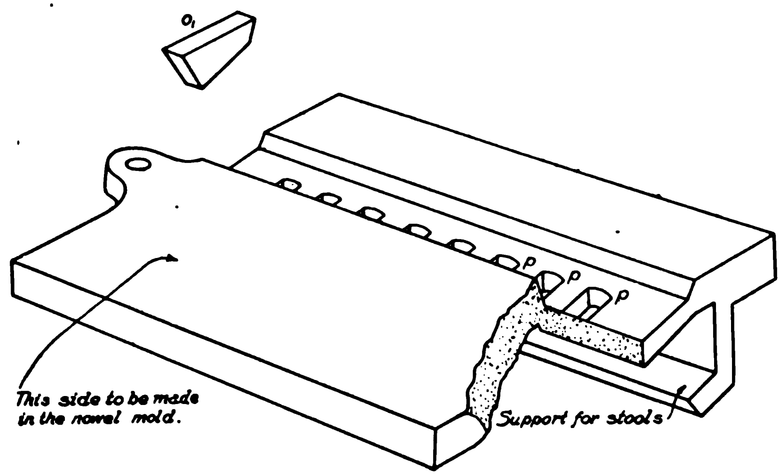


Fig. 314. Diagram of Stripping Plate, One End Broken to Show Holes through Which Pattern Is Drawn

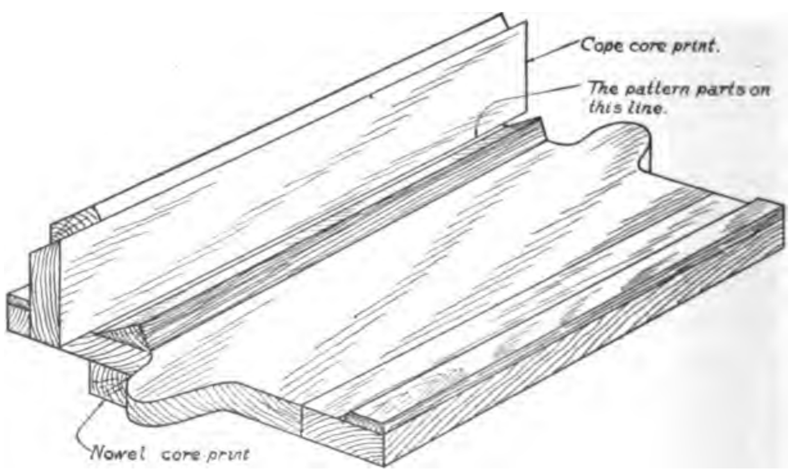


Fig. 315. Pattern for Stripping Plate

Plate Pattern. The plate is made of narrow strips of stock, glued so as to reverse the heart side of adjoining pieces. It will not be necessary to spline these patterns, for only one casting is

usually required and the pattern is generally molded as soon as it is completed.

Molding. What is to be the top of the casting is molded in the dry mold so as to be sure of obtaining a clear surface. Most

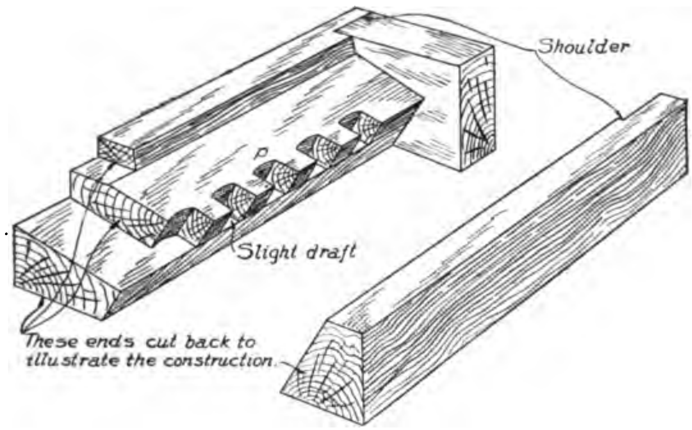


Fig. 316. Core Box for Core, Fig. 317

of the causes of imperfections in castings rise to the top of the mold while the metal is being poured, and thus, if there are gas or dirt blowholes in a casting, they will be found in the cope side of the casting. The casting is parted where shown, and the cope part of the pattern should be located on the drag with two dowel pins.

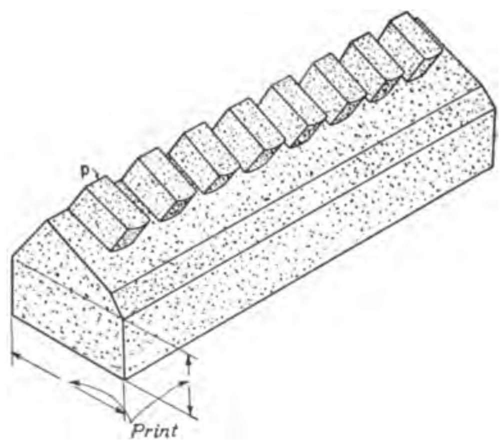


Fig. 317. Dry-Sand Core for Making Holes in Stripping Plates through Which Pattern Is Drawn

Coring. The core for the cope shall be made in a skeleton core box. No sketch is shown of this core box, but its construction would be similar to the core box for the part *g*, illustrated in Fig. 318. Fig. 316 illustrates the dry-sand core used in the drag mold, and Fig. 317 the core box for the core. This sketch shows the box

partly assembled and cut away so as to illustrate the construction. When it is certain that the parts are accurately cut to the required dimensions, they should be nailed and glued. One end is fastened to one side of the box, and the opposite end to the other side. No dowel pins are required as the shoulder holds the sides in alignment. Produce a slight draft to the parts forming the holes p, and a filing finish of about $\frac{1}{32}$ inch should be allowed on the sides of these holes.

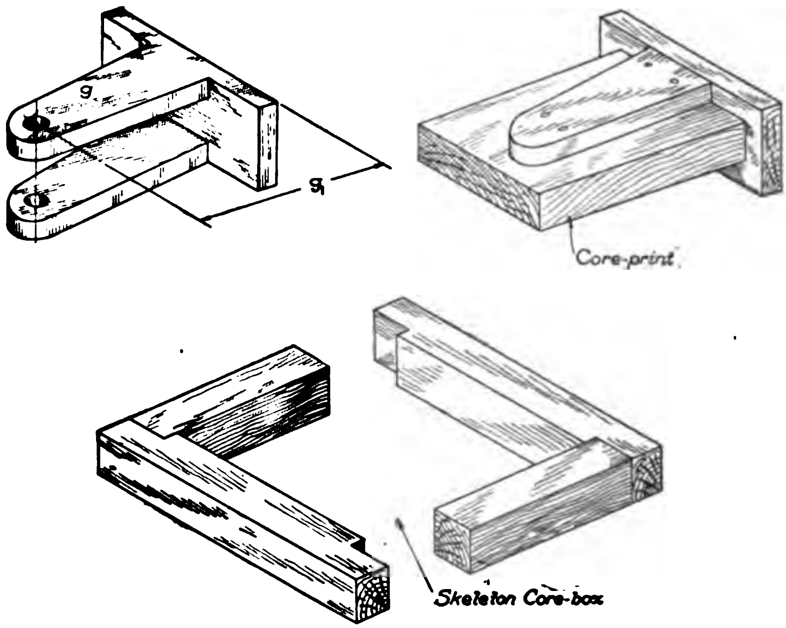


Fig. 318. Casting Pattern and Core Box for Part g, Fig. 312

Brackets. The sketches of the parts g and k, Figs. 318 and 319, should readily explain themselves. A dry-sand core is used to mold the part g, a sketch of the pattern and skeleton core box being given in Fig. 318. This was deemed necessary owing to the length of the dimension g_1. At best, the pattern would be quite fragile. The pattern for the part k, Fig. 319, should be made without a core print.

The master pattern and core box for the part c, Fig. 320, which is the pattern for the drag machine, are illustrated in Figs. 321 and 322. When making the wood pattern, double shrink should be allowed, and a filing finish of not over $\frac{1}{32}$ inch should be added

to all surfaces. The sketch of the core box shows a construction similar to that of those described in Part II, Pattern Making. The round hole at the lower end of the casting is to be finished to slide easily over the stool.

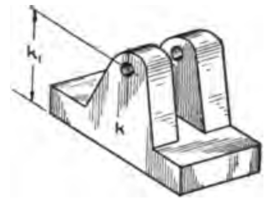


Fig. 319. Sketch of Cast-Iron Part *k*, Fig. 312

Use of Stool. Whenever it becomes necessary to strip an internal surface of a pattern, as illustrated in the socket or housing for the hardwood bearing used in the holder frame, Fig. 308, some means must be provided to support the molding sand, and this part of the equipment is called a *stool*. Illustrations of the stool for this pattern are shown in Figs. 312, 313, 323, and 324.

The top surface of these stools are made to the form of the hole or recess which it is desired to strip, and are usually yoked to the underside of the stripping plate. In this case, a projection cast to the underside of the stripping plate serves as a support for the stools. They are to be made of machine steel, and, together

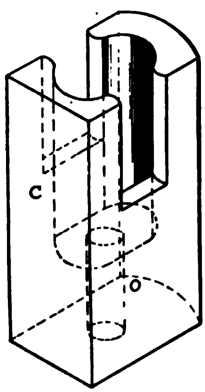


Fig. 320. Casting for Pattern *c*, Fig. 312

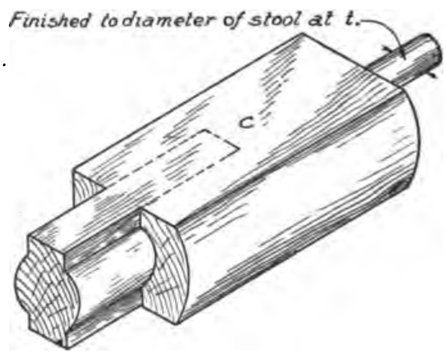


Fig. 321. Master Pattern for Part *c*

with the levers and links, Fig. 325, do not require a pattern, but accurate sketches or drawings, preferably full size, should be made by the pattern maker for these parts for the use of the metal-pattern maker.

Owing to the expense of the stripping plate equipment, this method should not be employed unless some feature of the casting prohibits the use of the simpler methods.

Use of Match Plate. A large part of this pattern which will be molded in the cope, has an abundance of draft, and as the other parts are not over ½ inch thick, a slight draft can be allowed to these parts, and a draft of fully 1 inch per foot can be allowed in the square hole. Therefore, it will be perfectly practical to mold

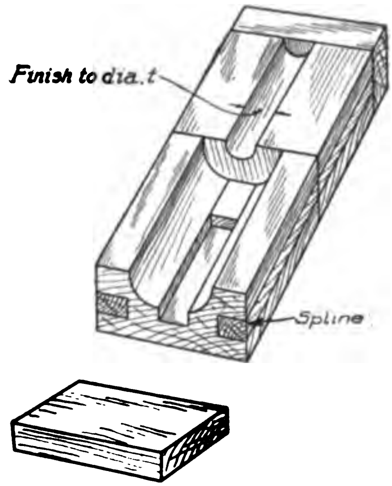


Fig. 322. Core Box for Master Pattern, Fig. 321

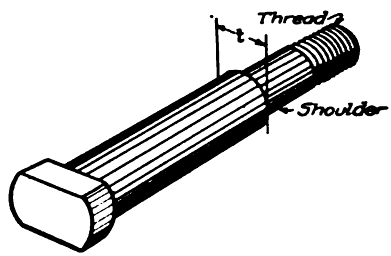


Fig. 323. Sketch of Stool *e*, Fig. 312

this side of the casting on a match plate, Fig. 326, and, while a pneumatic vibrator is shown, possibly it may not be necessary. The vibrator is operated while the plate is being drawn or lifted from the cope mold, causing a very rapid vibration to the pattern and plate, and greatly facilitating the drawing of intricate patterns.

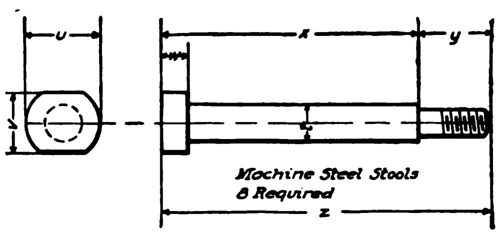


Fig. 324. Drawing of Steel Stool, Fig. 323

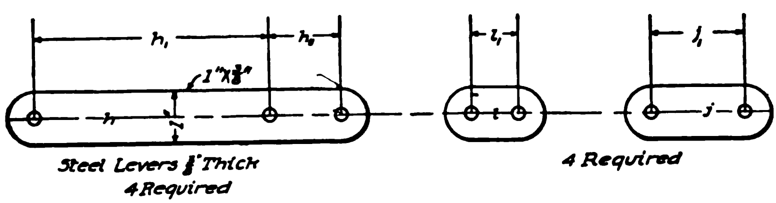


Fig. 325. Machine Steel Lever and Links

The iron plate should be finished on both sides, as the parting must match that made on the drag machine. The part q_1 is a

separate casting, and this must be machined to fit the recess q in the stripping plate.

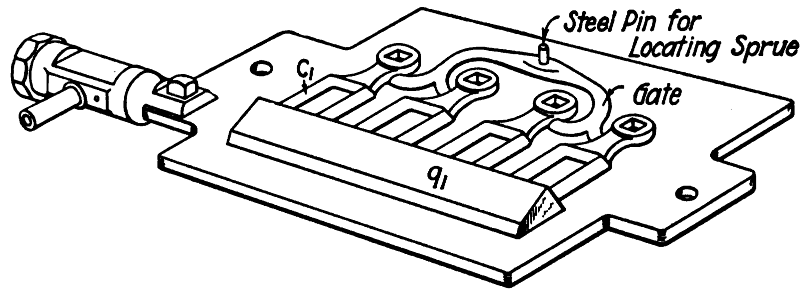


Fig. 326. Match Plate for Cope Mold with Vibrator Attached

Fig. 327 illustrates the master pattern. Double shrink and a file finish must be allowed.

Gate. A pattern for the gate, Fig. 328, must be furnished, and is usually made of cast brass. The location of feeding into the mold and its dimension should be suggested by the molder. It never should feed against a green-sand core, as the core would very likely be washed away.

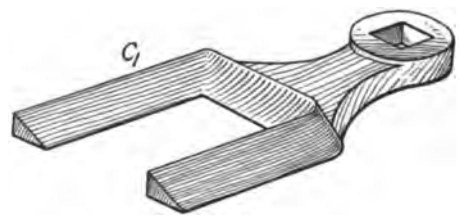


Fig. 327. Master Pattern

The parts q_1, c_1, and the gate pattern are attached to the plate with flat-head machine screws.

Alignment. Of course the alignment of the patterns on the cope and drag machines must be very exact to produce perfect castings, but this is the work of the metal-pattern maker. To avoid errors, there should always be a trial casting made and accepted before the outfit is passed to the foundry ready for the commercial product.

Fig. 328. Master Pattern for Gate

Use of Roll Back. Figs. 329 and 330 are illustrations of the cope and drag machines for molding the cover. The distinctive

feature of the pattern for the cover is the roll-back method of drawing the pattern on the cope machine, which is illustrated in section

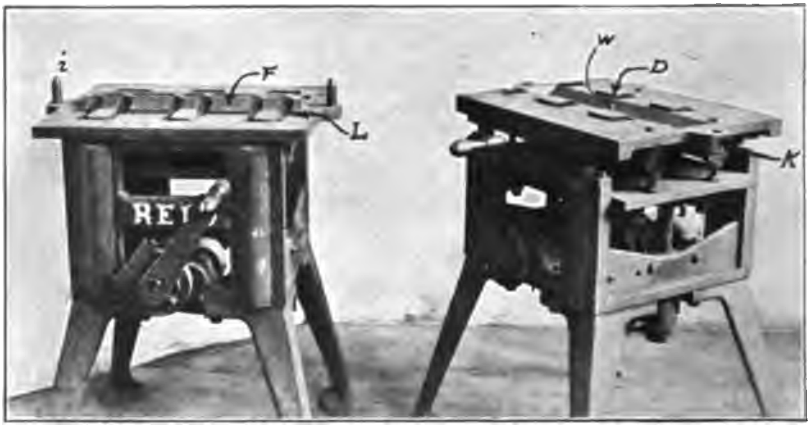


Fig. 329. Cope and Drag Machines for Molding Cover

in Fig. 331. The pattern c is shown in position for molding and also after being drawn. The patterns $c c$ are assembled on the pin P and mounted in the forged yoke or hanger H, which is bolted

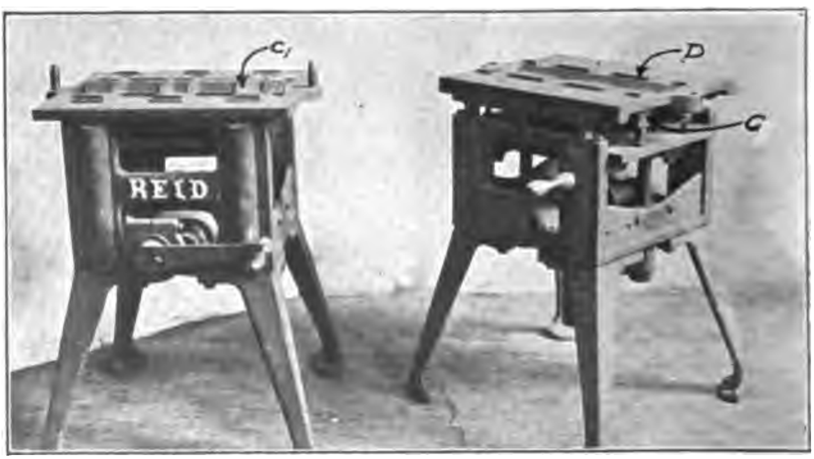


Fig. 330. Cope and Drag Machines with Pattern in Position for Molding

to the underside of the stripping plate B. The heads of the set screws which are illustrated on the draw plate A press against the

patterns at E, raising the patterns to the desired height. Upon lowering the draw plate, this allows the coil springs which are

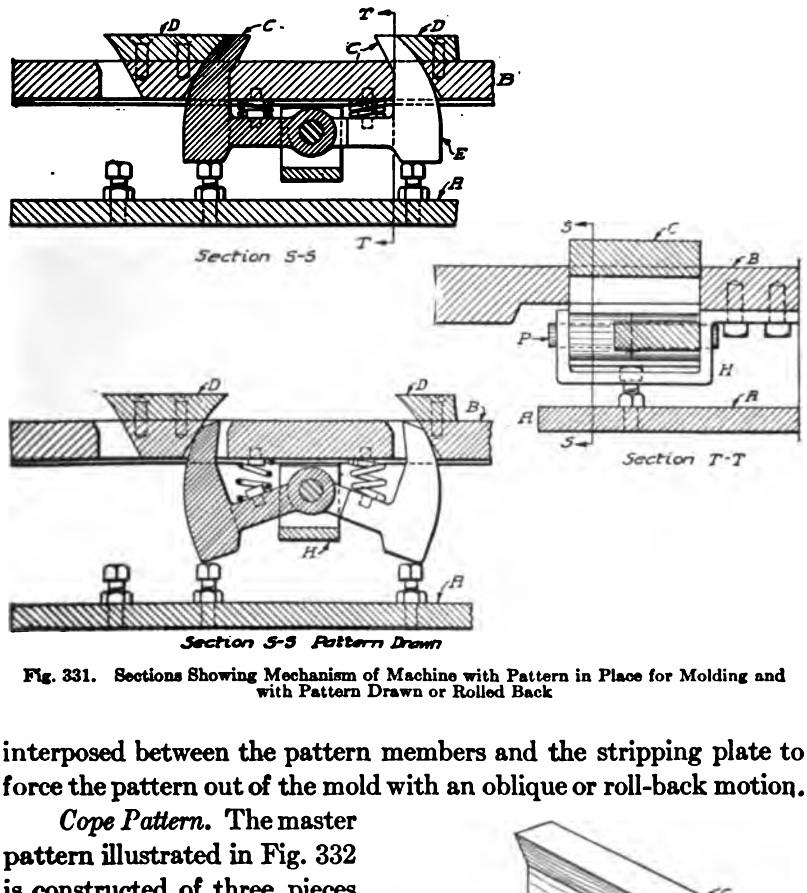


Fig. 331. Sections Showing Mechanism of Machine with Pattern in Place for Molding and with Pattern Drawn or Rolled Back

interposed between the pattern members and the stripping plate to force the pattern out of the mold with an oblique or roll-back motion.

Cope Pattern. The master pattern illustrated in Fig. 332 is constructed of three pieces of stock, nailed and glued together. As in the case of all master patterns, use the double-shrink rule and also add a filing finish allowance of about $\frac{1}{32}$ inch to such surfaces as form the pattern. Two castings are required from this master pattern for each pattern mounted on the machine. Fig. 333 illustrates the forged yoke H.

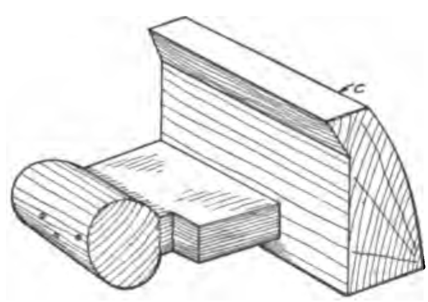


Fig. 332. Master Pattern

Cope Stripping Plate. A perspective view of the stripping plate for the cope machine is illustrated in Fig. 334. The angle and dimensions of the recess *J* in the top are determined from the original drawing, Fig. 308, and from the location of the patterns on the machine. A finish allowance of $\frac{1}{8}$ inch should be added to the top surface of the stripping plate, and cast-iron filler pieces riveted at the ends of the recess, as shown at *K* in Fig. 329. The core box for the cope stripping plate is shown in Fig. 335.

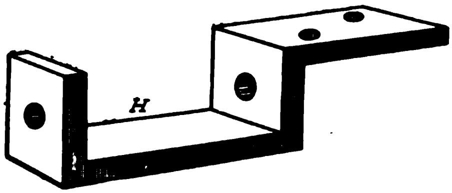


Fig. 333. Forge Steel or Iron Pattern Hanger

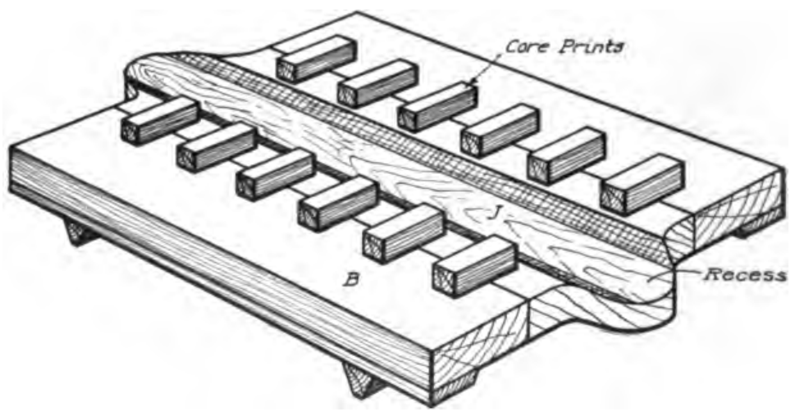


Fig. 334. Pattern for Cope Machine Stripping Plate

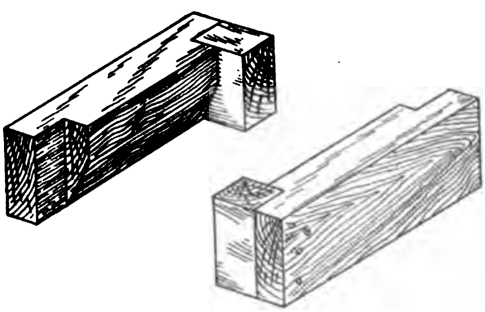


Fig. 335. Core Box for Cope Stripping Plate

Coring. The core prints must be accurately placed, and the length and width shall be slightly smaller than the finish sizes to allow for the accurate alignment of the metal patterns, and the cored hole should be enlarged below the top surface of the stripping plate. This will lighten the labor of fitting these holes to the patterns. The small

pieces of cast iron or steel, *D*, Fig. 331, are fastened to the top of the stripping plate with flat-head machine screws.

Drag Stripping Plate. Cope the parting to the top of the pattern, and a recess to match this is planed in the top of the drag

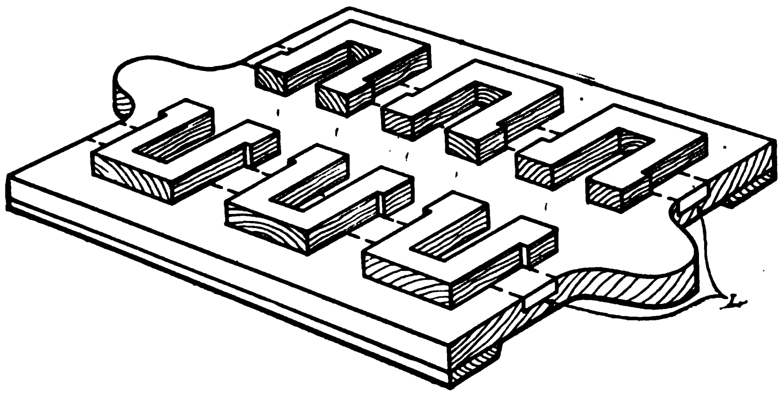


Fig. 336. Pattern for Drag Machine Stripping Plate

stripping plate, as shown by the dotted line *L* in Fig. 336. These features are also to be seen in Figs 329 and 330.

Stop-offs should be screwed to the underside of the stripping-plate pattern, Fig. 334, as the pattern will be weakened by cutting

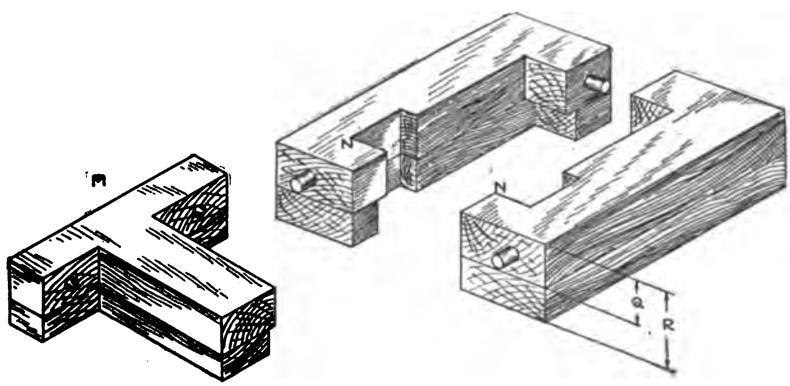


Fig. 337. Core Box for Stripping Plate

out the stock at *J*. This recess *J* can also be made with a dry-sand core if it is desired not to weaken the pattern as suggested above.

Skeleton Core Box. The stripping plate for the drag machine is illustrated in Fig. 336, and the core box in Fig. 337. As this construction is largely repetition, the cuts should explain themselves. This skeleton core box, however, has one new feature; it is made in three parts. After the core has been rammed, the end M is drawn, the ends of the sides $N\,N$ holding the core sand so that end M is stripped out of the core. The sides can then be removed.

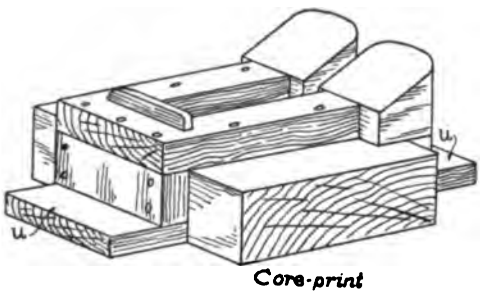


Fig. 338. Master Pattern for Cover

This illustration clearly shows the method of enlarging the lower end of the holes which are cored in the stripping plate. The dimension Q shall be the height of the core print plus $\frac{3}{8}$ inch, and R shall be the total thickness of the pattern including the core print.

Fig. 339. Pattern for Part *F*, Fig. 329

Drag Pattern. Fig. 338 shows a perspective sketch of the master pattern for the nowel or drag machine. This pattern must be extended to reach through the stripping plate down to the draw plate. The feet marked $u\,u$ shall have a metal-finish allowance on the underside, and the weight of the casting can be greatly reduced by coring. The core print is to be made first and the other parts nailed and glued to it. Use great care to have all parts very accurate, keeping the dimensions slightly over size, for the exposed portions

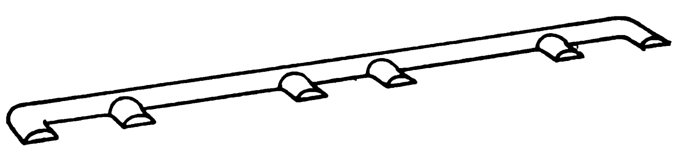


Fig. 340. Master Pattern of Gate for Holder Frame Cover

will be file-finished. A simple skeleton core box will do for this core.

The part F, Fig. 339, must be finished to the same dimensions as the recess J on the cope machine. This piece is screwed to the center of the nowel stripping plate, as shown in Fig. 329.

Gate. The master pattern for the gate is shown in Fig. 340. This is a brass casting and is illustrated in Fig. 329 fastened to the top of part F. A steel pin, shown at W on the cope machine in Fig. 329, locates the sprue.

Advantages. These machines are in successful operation, the improvements over the hand-rammed castings being more castings per flask, doing away with the expense of making and setting the dry-sand cores, and the uniformity of the castings requiring less fitting.

GREEN-SAND CORING

Expanding Pattern

Characteristic Usage. The bearing-cap casting seen in Fig. 341 was first produced with a hand-molded pattern, using a heel core

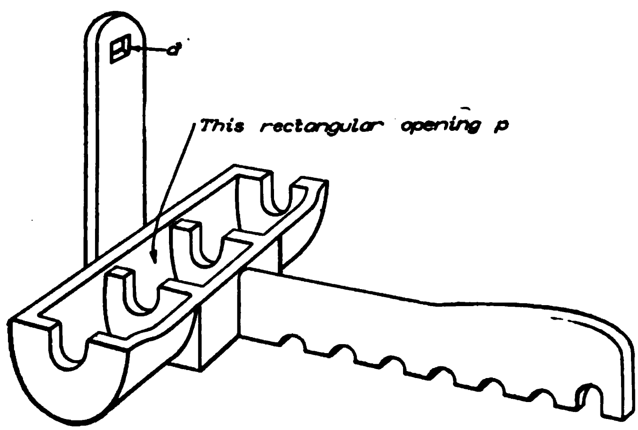


Fig. 341. Sketch of Bearing-Cap Casting

to mold the square hole in the upright position shown at d. This heel core and the setting of it was an expense; there was always an unevenness at the surface of the casting caused by the heel of the core, which had to be ground smooth. To avoid these objectionable features, what is called an expanding pattern may be adopted.

Molding Process. The principal stages of the molding process will be considered to give a clear conception of the purposes of the several parts.

Fig. 342. Drag and Cope Machines in Position for Molding

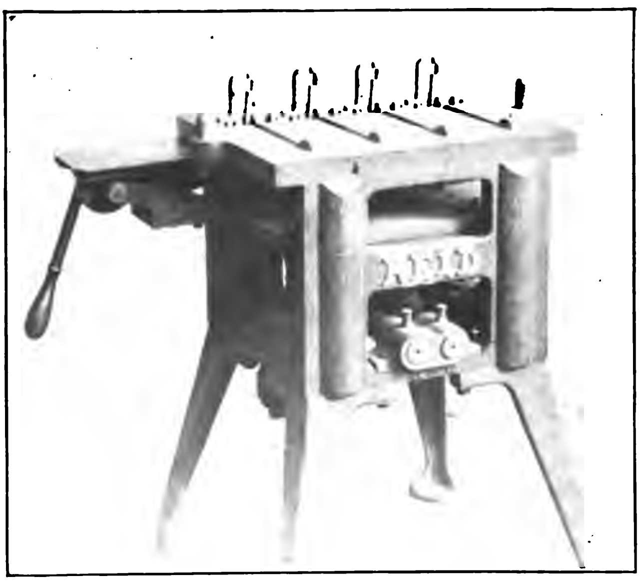


Fig. 343. Pattern Expanded Ready to Be Drawn through the Stripping Plate

Drag Mold. Fig. 342 illustrates the cope and drag machine, with the patterns in position for molding. As the sand is rammed to cover the pattern *c*, the operator pinches the facing sand into

the hole *d* with thumb and forefinger. The handle *h* is then depressed, this motion opening or expanding pattern *c*, as illustrated in Fig. 343. The mold now has the dimensions required and a green-sand core that will form the square hole *d*. Lowering the draw plate *a*

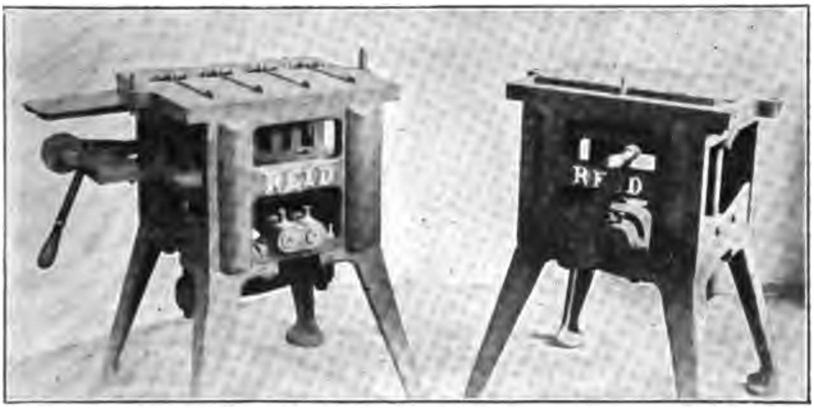


Fig. 344. Same Machines as Fig. 342, with Patterns Drawn

draws the patterns *c* and c_1 through the stripping plate *b*, and the drag mold is completed. The pattern c_2 is not drawn through the stripping plate, as enough draft can be given to this part to allow the mold to be easily lifted, the flask pins guiding the mold until the pattern is clear.

Fig. 344 illustrates both machines with patterns drawn.

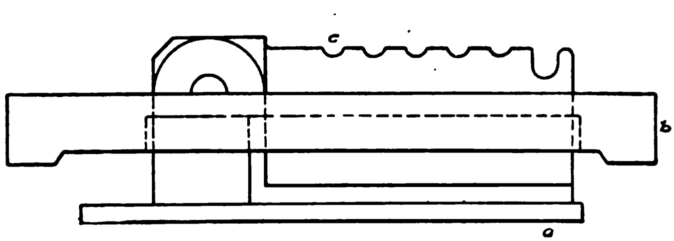


Fig. 345. End Elevation of Cope Machine

Cope Machine. Taking up the construction of the several parts, the cope machine will be fitted first. The stripping plate will be of standard dimensions, and it will be well to adopt several sizes and mount all patterns on these plates so as to avoid the ex-

pense of the numerous sizes of flasks required. The stock stripping-plate machines are built with circular and rectangular frames. The rectangular frames usually are 12 inches, 14 inches, 16 inches, and 20 inches square, but it is possible to extend the stripping and draw plate so that a 12- by 14-inch, 12- by 16-inch, and 12- by 20-inch flask can be used on a 12- by 12-inch machine. The machine for these patterns has a frame 14 inches by 14 inches, outside dimensions.

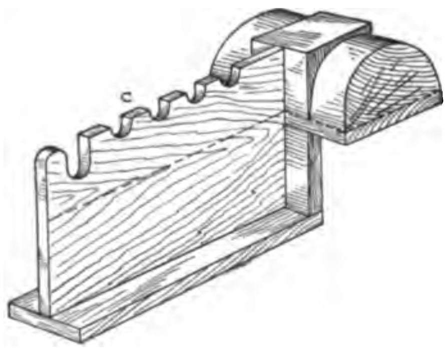


Fig. 346. Master Pattern for Cope Pattern *c*, Fig. 345

There are to be four patterns mounted, but, in describing the parts, only one will be referred to, it being understood that the four patterns are connected together and operated by the same motion. A section of the cope-pattern *c*, and stripping and draw plates are

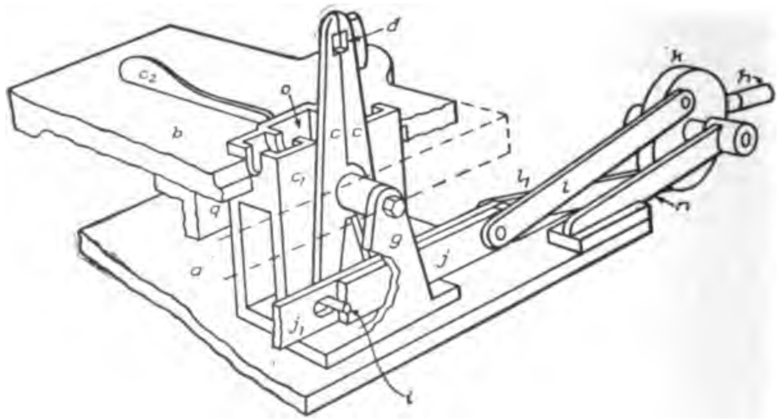


Fig. 347. Assembled View of Mechanism for Drag Machine

shown in Fig. 345. Core the holes in the stripping plate by the same method as used before. An illustration of the cope master-pattern *c* is shown in Fig. 346. That portion of the pattern above the dotted line is above the top of the stripping plate, and should

have a file-finish allowance. The bottom of the bolting flange should have a finish allowance of $\frac{1}{16}$ inch.

Drag Machine. The illustration in Fig. 347 is a sketch of the assembled parts of the drag machine. The stripping and draw plates are broken away, and the frame of the machine is not shown. Spacers must be furnished for this machine, as shown at *m* in Fig. 311. The stripping plate is bolted to the outside frame and the draw plate to the draw frame of the machine. The pattern is made of four parts. A master pattern for a bronze casting of c_2 shall be made, and this part is to be riveted to the stripping plate. Part c_1 is bolted direct to the draw plate. Parts *cc* are supported by the stand *g* which in turn is bolted to the draw plate *a*. The lower end of the right-hand pattern *c* is connected by a steel pin to the link j_1, not shown; the left-hand *c* is connected to the link *j* by a longer steel pin, which passes through a slot in link j_1, into a hole in link *j*.

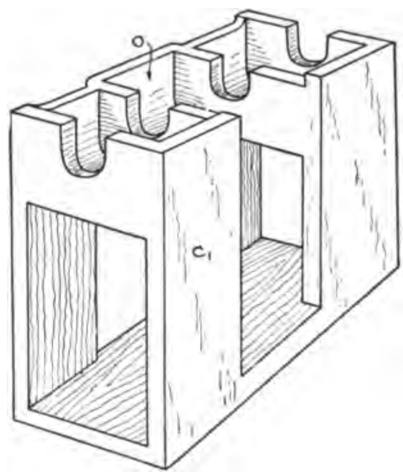


Fig. 348. Drag Pattern c_1, Fig. 347

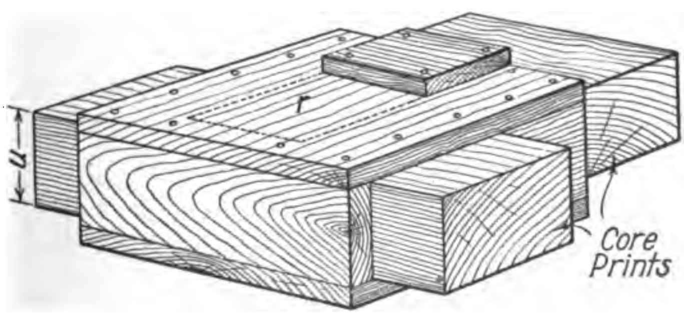


Fig. 349. Master Pattern for Part c_1, Fig. 348

Connecting the link *j* and j_1 by the arms *l* and l_1 to diametrically opposite points on the disk *k* transmits an opposing motion to links *j* and j_1, moving the parts *cc* away from each other, pressing the

mold to the form desired, and leaving a green-sand core at *d* to form the square hole in the casting. The draw plate can then

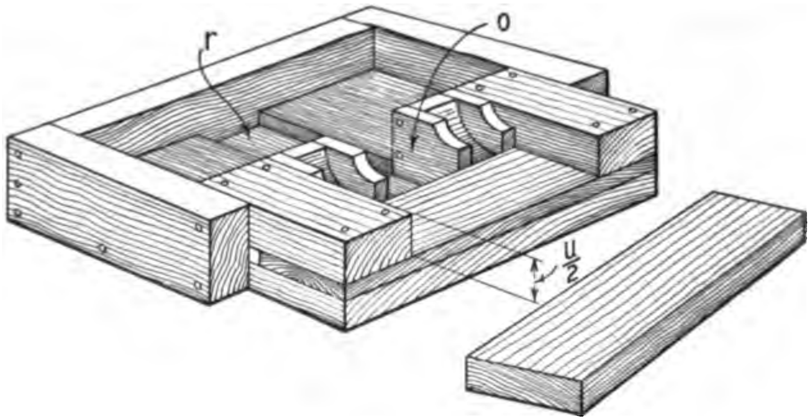


Fig. 350. Core Box for Pattern, Fig. 349

be lowered, drawing and stripping the patterns *cc* and c_1 through the stripping plate. The links *j* and j_1 extend the length of the

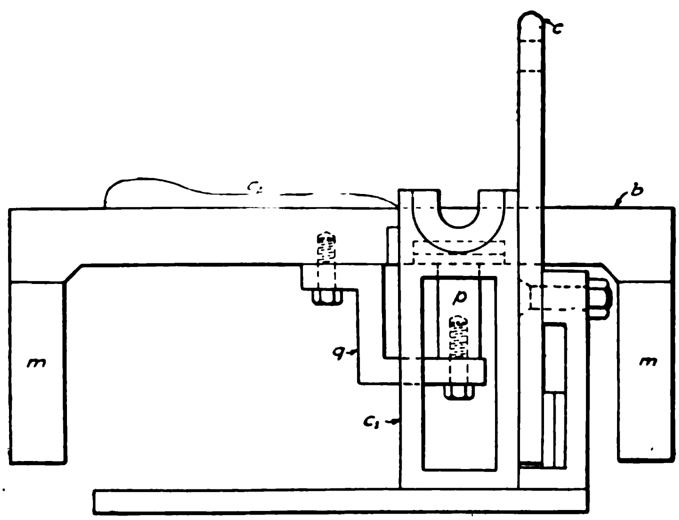


Fig. 351. Nowel End Elevation of Drag Machine

machine, conecting with the four patterns. The recess *o* is stripped with a stool *p*, Figs. 351 and 357. These stools and the yoke *q*,

Figs. 347 and 356, upon which they are attached, are bolted to the underside of the stripping plate, as shown in Fig. 351.

Drag Pattern. The pattern c_1, an illustration of which is shown in Fig. 348, will require a finish allowance of $\frac{1}{16}$ inch on the under-

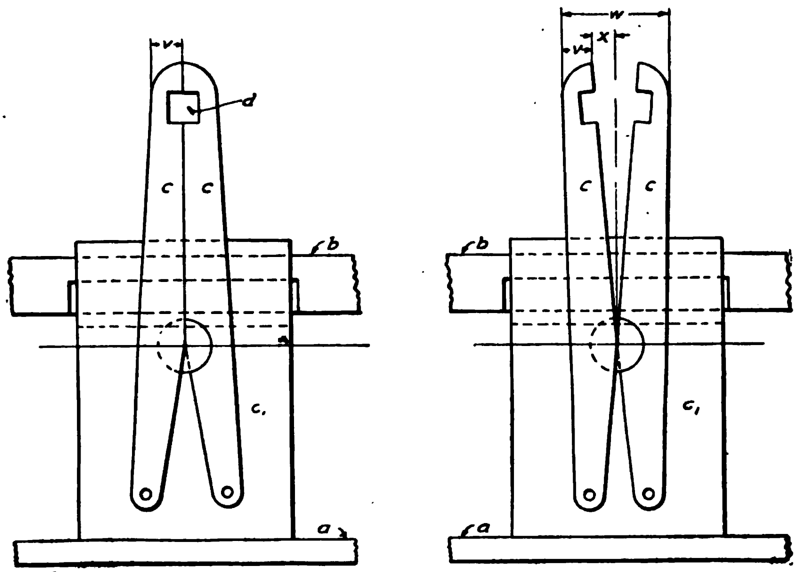


Fig. 352. Expanding or Crush-Back Motion

side of the foot, and a file-finish allowance on that part which protrudes above the stripping plate. The master pattern with its core

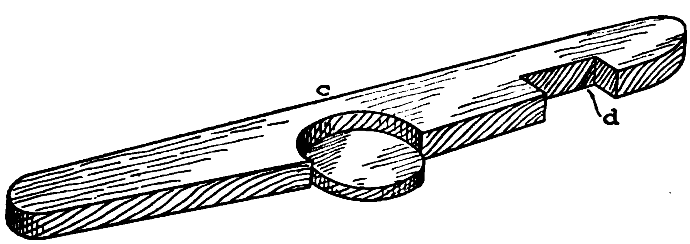


Fig. 353. Master Pattern of Part c, Fig. 352

box is illustrated in Figs. 349 and 350. As before, the core-print stock should be dressed to dimension first, and that part of the pattern representing iron nailed and glued to it. Use the double-shrink rule or allow double shrinkage when making these master

patterns, and allow planing, turning, and file finish where needed. The core box, one side of which is shown removed so as to show its construction, is intended to make two cores which when pasted, will make the core as used in the mold.

The surface on the pattern enclosed by the dotted line at *r* shall be shellacked to same color as the core prints, as the core cuts through at this point, and if it is not indicated in this manner the molder would be in doubt as to whether the core should or should not cut through. Molders have been known to file the core to be sure of getting metal in a case like this, the reasoning being that if a hole is wanted it can be cut out easier than the hole could be filled in, should the core be allowed to cut through. The molder should not be left to surmise what is wanted. Always mark patterns by some understood method so that there will be no need of verbal instructions to the molder.

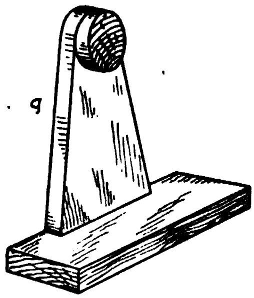


Fig. 354. Stand—Support for Pattern *c*, Fig. 353

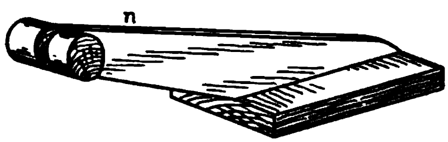


Fig. 355. Bracket and Bearing for Operating Device

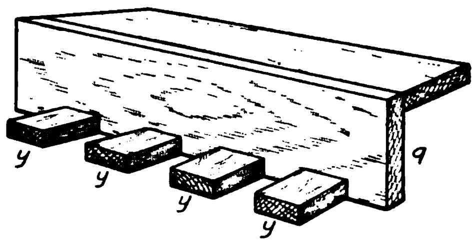


Fig. 356. Stool Yoke

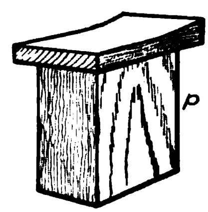


Fig. 357. Master Pattern of Stool

Expanding Motion. Fig. 351 is an end view of the nowel or drag mounting, and in Fig. 352 the layout of the patterns *c c* is illustrated. Make a full-size layout of this motion; the dimension *v* shall be such that when the pattern *c* is drawn it will not strike and

break down the green-sand core *d*. This dimension $v+x$ must be slightly less than $\frac{w}{2}$, w being the dimension of the width of the pattern.

Fig. 353 illustrates the master pattern of the part *c*. Two castings from this pattern can be fitted together as shown in Fig. 352. The length from the center to the lower end is optional, but the top of the stripping plate should be kept as low as possible. The operator can work easier and mold the pattern quicker if he does not have to shovel the sand too high.

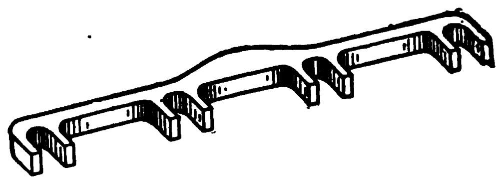


Fig. 358. Master Pattern of Gate

The parts *g* and *n*, illustrated in Figs. 354 and 355, and their object, as shown in Fig. 347, should explain all that is necessary. Their dimensions are fixed by the dimension requirements of the commercial casting.

Fig. 356 illustrates the stool yoke *q*. The parts *y* extend into the pattern c_1, as shown in Fig. 351, and the stool *p* is attached as shown. The top of this stool, a sketch of which is shown in Fig. 357, is fitted to the recess *o* in the pattern c_1, shown in Fig. 348, and is used to prevent the sand in this recess from following the pattern when the pattern is drawn; in other words, it acts in just the same manner as the stripping plate does with the outside of the pattern.

The sheet-metal cover over the expanding-motion device, shown in Fig. 342, is intended to prevent the molding sand getting into the bearings and causing excessive wear. The handle *h* will be made of machine steel, threaded on the machine end, and screwed into the periphery of the disk *k*, as shown in Fig. 347. This handle should be designed to be easily removed, while storing the machine, to prevent breakage.

Gate. Fig. 358 illustrates the master pattern for the gate pattern. This will be a bronze casting and is fastened to the cope machine. A steel pin should also be fitted to this gate pattern to locate the sprue.

Double-Draw Stripping-Plate Machine

Typical Feature. The feature of this arrangement used for molding the jaw clutch, Fig. 359, is that the pattern is used as a stripping plate for the hub and the clutch jaws. It was specified that there was to be no draft on these parts, and that the corners between the disk *g* and the jaws *f* must be very sharp and clean.

Construction. In Fig. 360 the right-hand section is taken midway between two jaws, and the left-hand section through the center of one of the jaws.

Stripping Plate. The stripping plate is constructed to the same dimensions as used for the other castings. As described, it is fitted for one casting mounted on a square frame machine, but a round machine will do as well, or two patterns can be fitted by extending the plates *a* and *b*. The pattern hole in the stripping plate is cored and machined to dimension, and the underside must be finished parallel to the top side for a space of about ½ inch outside the hole.

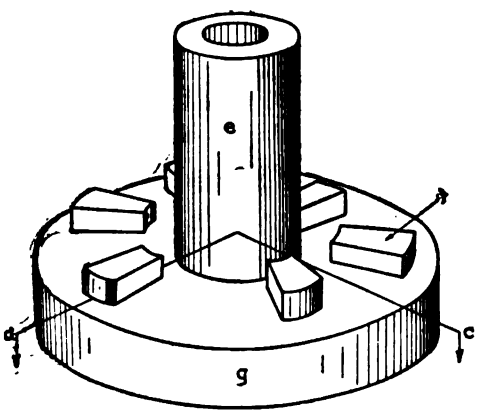


Fig. 359. Casting Molded on Double-Draw Stripping-Plate Machine

Disk Pattern. A shoulder is made on the outside of the disk pattern *g* to act as a stop to prevent the pattern from being raised above the height desired. The dimension *i* should be such that pattern *g* will be held rigidly between the stripping plate and the draw plate when the latter is in a raised position.

Fig. 361 illustrates the master pattern for disk pattern *g*. The holes through which the jaw patterns *f* pass are designed to be made by the metal-pattern maker, the stock not being over ¼ inch thick. Allow a finish of $\frac{1}{16}$ inch to ⅛ inch on all outside surfaces, but the inside is not to be machined.

Hub Pattern. The pattern for the hub *e* can be made of a casting or of machine steel, and is bolted to the draw plate, as shown in section in Fig. 360.

Jaw Pattern. Six castings will be required of the jaw pattern *f*. A sketch of the master pattern is shown in Fig. 362. A file finish is to be allowed to the upper end and a planing or milling finish of $\frac{1}{16}$ inch allowed to the underside of the foot. These parts are to be bolted to the draw plate.

Draw Rods. There are to be three bosses on the underside of the disk, illustrated at *j* in Fig. 361, and into tapped holes in these

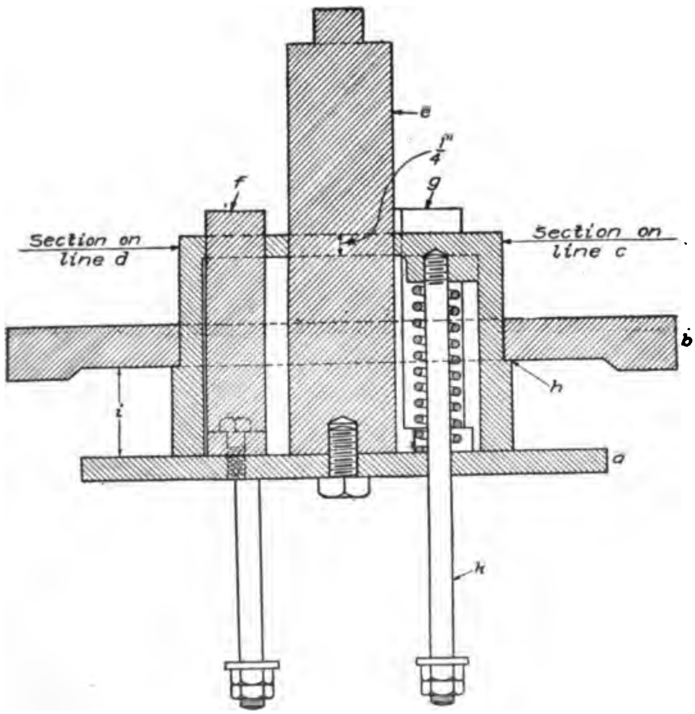


Fig. 360. Section of Pattern, Stripping Plate, and Draw Plate for Casting, Fig. 359

bosses ½-inch soft steel rods are fitted, as shown at *k* in Fig. 360. These bosses are located so as to come between every other jaw pattern, and holes are to be drilled in the draw plate through which the steel draw rods *k* will pass.

Open springs are placed on the draw rods between the pattern *g* and the draw plate, and they should be capable of holding the pattern *g* in place until the hub *e* with the jaws *f* have been stripped, when the underside of the draw plate, upon striking the nuts on the

draw rods, draws the pattern *g* through the stripping plate. In raising the pattern the operation is reversed, the draw plate forcing

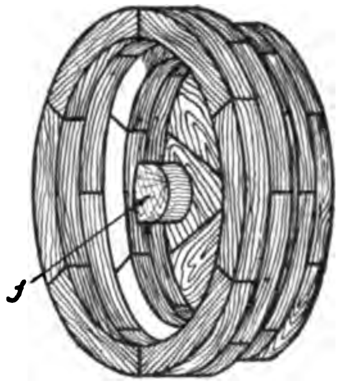


Fig. 361. Master Pattern of Disk

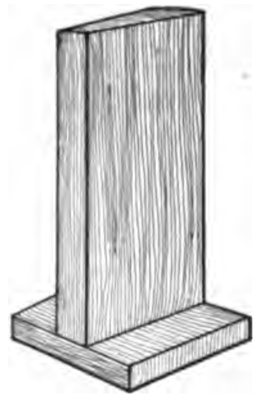


Fig. 362. Master Pattern of Clutch Jaws

the pattern *g* into the correct position at the end of its upward motion.

Cope Plate. The cope mold is made on a cope plate having only the cope core print, the locating pin for the sprue, and the flask pins.

Gate. The gate pattern will be similar to that used for the flange coupling, as is seen in Fig. 298.

Green-Sand Core Box

Suitability. Such castings as short lengths of pipe, and elbow and T-pipe fittings of reasonable diameter lend themselves readily to this method of molding. It would not be economy to equip for this method if a very few castings are required, or where the requirements would suggest the costly equipment for casting pipes on end. Like other methods of molding, it has its scope, and the pattern maker should not attempt to design an equipment for this work without first consulting with the master molder.

Pipe Pattern. The casting considered will be a short length of cast-iron pipe, 72 inches long, 6 inches inside diameter, and flanged at one end. The construction of the pattern will not be considered, as it is a parted pattern with a detachable flange similar to that considered before. In fact there is no difference in the pattern used with a dry-sand or with a green-sand core.

Green-Sand Core. Fig. 363 illustrates the iron core box, the halves being hinged together as shown at *a*. The arbor, Fig. 371,

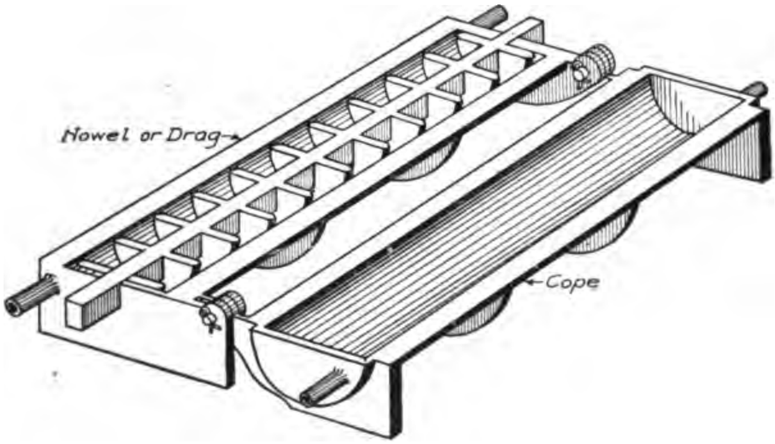


Fig. 363. Iron Core Box for Green-Sand Core

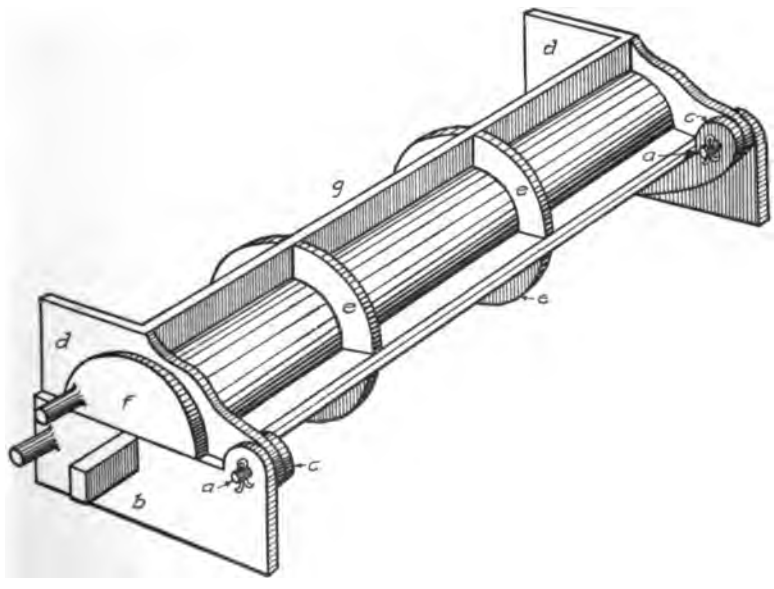


Fig. 364. Core Box Closed

is placed in the drag half, the ends extending through the notched ends of the core box. Green sand is rammed in drag and cope and struck off level with the top of each half. The core box is closed

by lifting on all four handles like closing a book, print upward, then rolling over into position shown in Fig. 364. The upper half

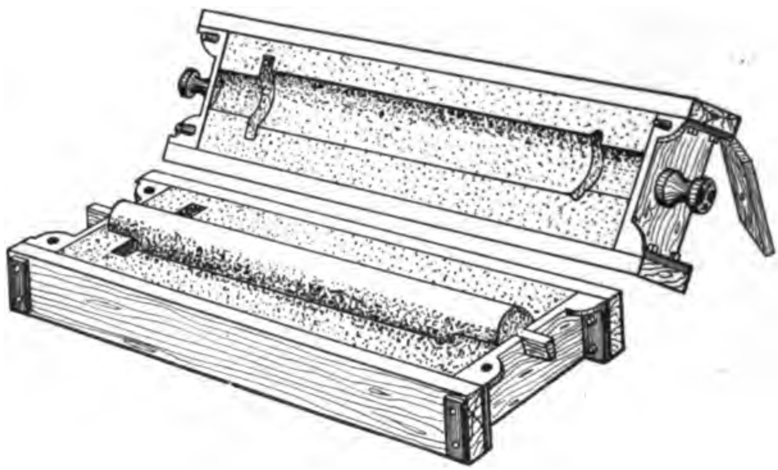


Fig. 365. Pipe Core Set in Mold

of the core box can now be returned to its first position, leaving the cope half of the core resting on the drag itself. The complete

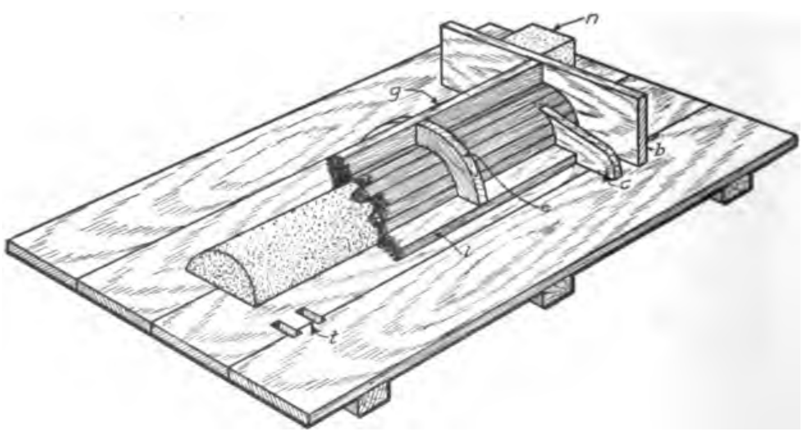


Fig. 366. Start of Core Box

core can then be drawn from the core box—lifting it by the arbor extensions—and placed directly in the mold. The flask ends should be notched to receive the arbor extensions, as illustrated in Fig. 365.

Core-Box Construction. Several methods of constructing the master pattern for the core box may be utilized. As only two castings are required—one for each half of the core box—the quickest

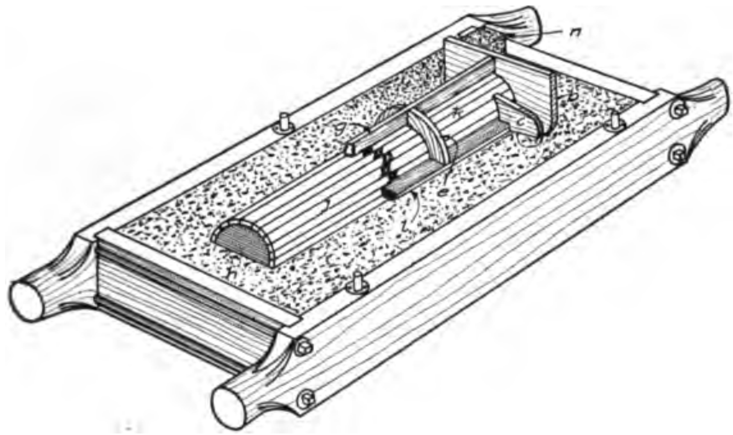


Fig. 367. Pattern Assembled on False Cope Ready for Ramming Cope Mold

method of constructing the pattern should be used, provided the results are accurate. A nailed and glued pattern using a green-sand core for molding the inside would produce the smoothest casting, Fig. 366. The pattern, however, would be very fragile, and a form

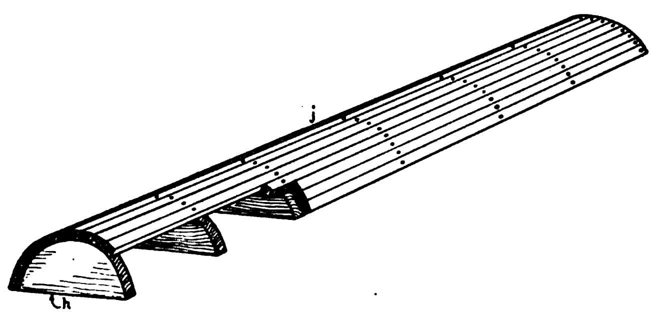


Fig. 368. Wooden Form

should be made to fit the inside to hold it in shape while ramming the drag mold.

Use of Form. The construction considered will be to furnish the molder with separate flanges and lagging, and assemble the parts on a wooden form, Fig. 367, or a dry-sand core can often be used in place of the wooden form.

The form, Fig. 368, is constructed of thin strips of wood nailed to several semicircular heads shown at *h;* the length to be the inside length of the core box. The strips of lagging should be about $\frac{3}{8}$ inch thick; the edges need not be fitted together, but the diameter must be of the dimension required. The pieces *h* should be made $\frac{1}{8}$ inch over the half circle; that is, the center of the circle is $\frac{1}{8}$ inch in from the edge, as shown at *i* in Fig. 369. This $\frac{1}{8}$ inch is for a metal finish allowance on the face of each half, as the core box must close

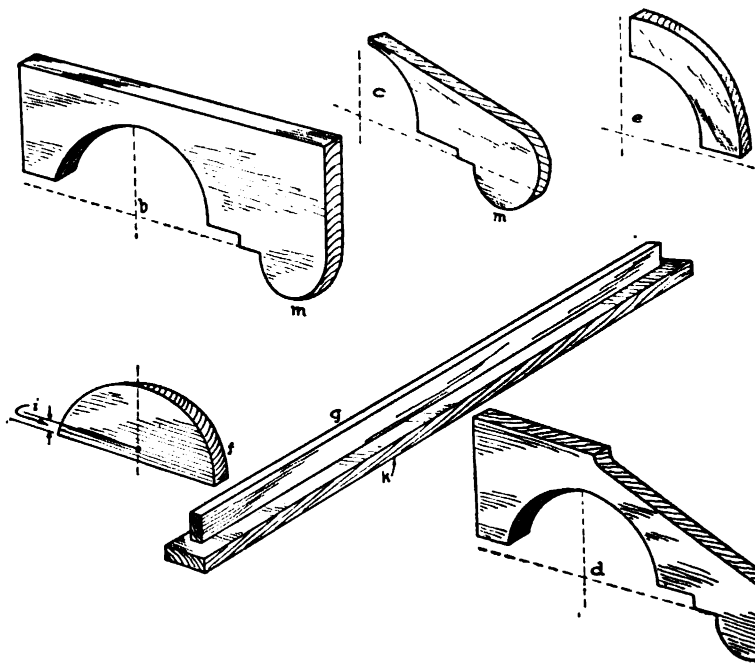


Fig. 369. Ends, Flanges, and Hinge Lugs

accurately its entire length. Part *b* is the end flange, and *c* is a lug, shown in Figs. 367 and 369. The space between *b* and *c* is wide enough to allow the part *d* to turn easily. This form of hinge, having a double shear to the steel pin *a,* is very strong and much better than if only one lug were used on each half of the core box. The part *e* is the transverse flange, while *f* and *d* form the end of the cope half. Lagging is to be provided which should be about $\frac{1}{4}$ inch thick and $\frac{1}{2}$ inch wide. This is shown in Fig. 367 at *k,* and

the part g, Figs. 365 and 367, is nailed to one of these strips of lagging, as shown in Fig. 369.

Fig. 367 illustrates the several parts of the pattern assembled on what is called a false cope. This cope flask is rammed and struck off level with the joint; the form j is placed in position; the flanges l and the lagging k are laid upon this form. The ends b and the lugs c are located, and that part m of the hinge lugs is bedded into the false cope, Fig. 367. The drag mold can now be rammed and turned over, the false cope removed and the form j removed. The cope mold is now made and the pattern can be drawn.

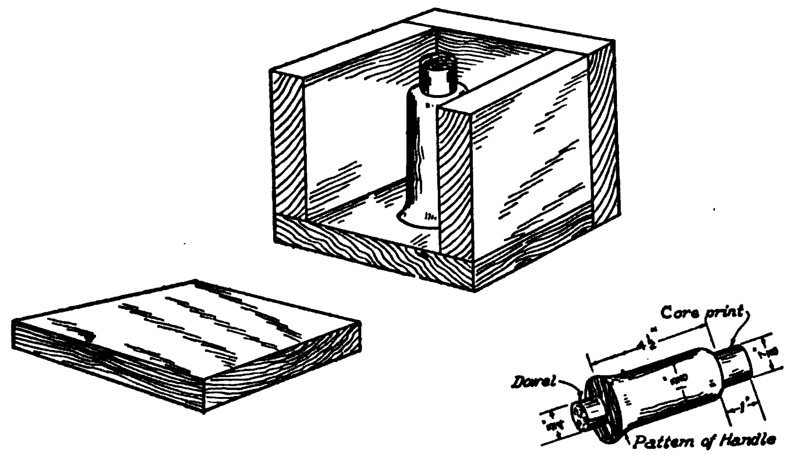


Fig. 370. Core Box for Cast-Iron Handle

If it should be desired to mold the inside of the core-box casting with a dry-sand core, the form j may be omitted and the pattern parts assembled directly on this core.

Handles. Handles should be cast on each half of the box, as illustrated in Figs. 364 and 365. These handles are molded in a dry-sand core and rammed in the mold, as shown at n in Fig. 367. The core box for this handle is illustrated in Fig. 370. The length of the handle should be about $4\frac{1}{2}$ inches, the diameter about $1\frac{3}{8}$ inches, and the diameter of the hole $\frac{7}{8}$ inch. Allow about 1 inch of core sand on each side of the handle pattern and a draft of fully $\frac{1}{2}$ inch on each side. The height or depth will be $5\frac{1}{2}$ inches for a handle of these dimensions, making the top end of the core print

flush with the top of the core box. A cylindrical stock core $\frac{7}{8}$ inch in diameter is pasted into this core, so as to cast a hollow handle.

Arbor. The skeleton frame used for reinforcing the drag half of the core is an iron casting. This is illustrated in Fig. 371. The pattern consists of a rectangular arbor *r* and of several patterns for the flanges *s*. These flanges should be notched to fit over the arbor, but need not be attached in any other way, the molder placing them in the position required; his judgment of the spacing would naturally be better than the pattern maker's. The end flanges should be placed at the extreme end of the core. The outside diameter *o* would be about $\frac{3}{4}$ inch less than the outside diameter

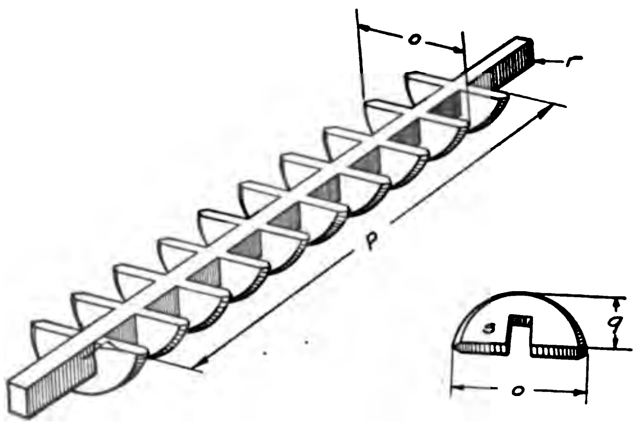


Fig. 371. Cast-Iron Arbor

of the core, and the thickness about $\frac{1}{4}$ inch. The outside circular edges should be chamfered to a thin edge, so as to prevent soft ramming under the flanges. The width *q* should be $\frac{1}{4}$ inch less than the half circle, as it is required to have the sand rammed over the top of the arbor. The arbor extensions at each end, however, shall be constructed to the center, so that the cope flask will rest upon these ends, preventing the arbor and core from lifting when the mold is poured.

HOLLOW ROLL CAST ON STEEL SHAFT

Split-Pattern Method

Construction. In the first of the two methods of making the cast-iron roll, Fig. 372, to be considered, the steel shaft is placed

in the mold, and, having been spotted with a drill on the portions which are in the hubs, is practically bonded with the hubs.

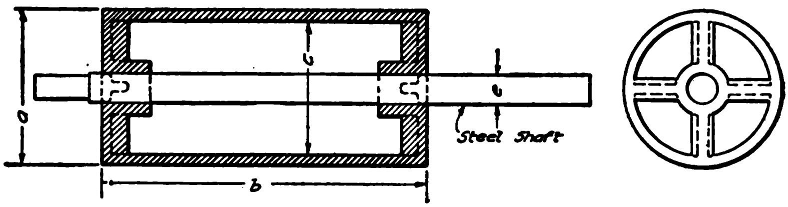


Fig. 372. Section of Cast Roll, Four-Arm Spider at Each End and Steel Shaft Cast In

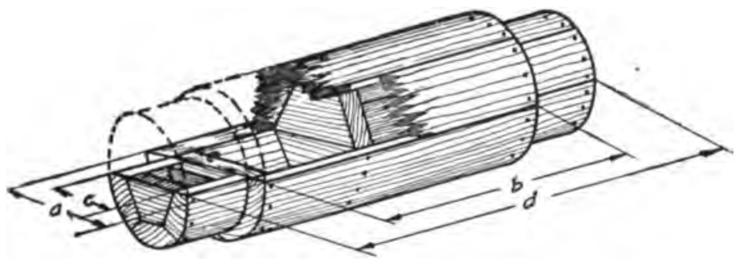


Fig. 373. Split Pattern for Cast-Iron Roll

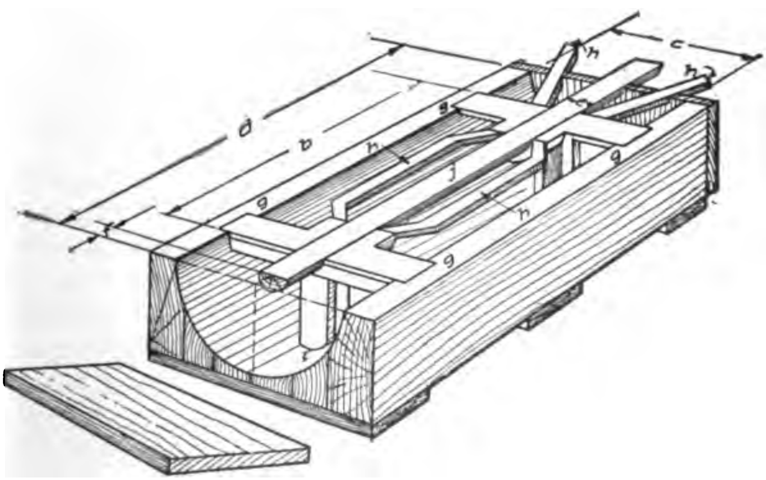


Fig. 374. Core Box for Making Roll by First Method

Pattern. The split pattern illustrated in Fig. 373 is constructed of wide lagging nailed and glued to heads. The core prints are assembled as separate members and fastened to the body of the

pattern with wooden screws. The pattern is to be assembled complete with dowel pins, and the halves are held together by metal lathe centers, such as considered on similar work in Part II, Pattern Making.

Core Box. The core box can be made of glued stock, as shown in Fig. 374, or a skeleton form of construction can be used if the roll is very large. The glued stock illustrated in this figure will probably stand up under the wear and tear of the foundry longer than the skeleton construction. Glue the bark side and the heart side of adjoining pieces of stock together, and the center pieces may be made of narrow stock, thus saving considerable material.

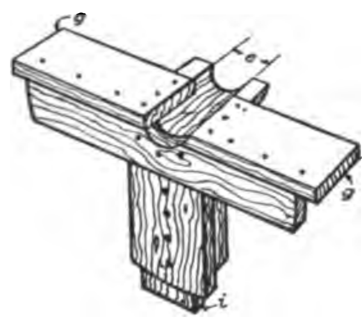


Fig. 375. Part of Core Box, Fig. 374

Cut the inside to a semicircle with a core-box plane. At *g* and *i* the stock is mortised to receive the ends of the arm pattern which is illustrated in Fig. 375. Two patterns will be required of this part as shown in *gg*, Fig. 374. The dimension *e*, Fig. 375, should be slightly larger than the diameter of the steel shaft. The part *j*, Fig. 374, which fits into the recesses *e* of the arm pattern is semicircular in section, and forms the recess in which the steel shaft is placed. The parts *hhhh* are patterns of the gate. They are not fastened to the arm pattern but are bedded in the top face of the core.

Operation. After ramming the core and bedding in the parts *h* and *j*, these parts together with the arm pattern are drawn, and the space is filled with molding sand. This molding sand prevents the core sand from settling when the core has been turned over onto its flat side. When pasting the halves together the steel shaft is placed in position.

The mold is cast on end, the sprues being connected to the gate *h*. The metal passes through the upper hub, then on into the lower hub and out through the arms, filling the rim; in this manner the steel shaft is brought to a very high temperature, which fuses the shaft with the hub castings and makes a very firm joint.

Stripping-Ring Method

Characteristics. The following description will show a second method for making the cast roll. This arrangement produces clean and accurate castings, the machine-finish allowance being $\frac{1}{8}$ inch. Fig. 376 illustrates the cheek flask *a* resting on and keyed to a cast-iron mold plate *d*. The open ring *b* on top of the flask is a stripping ring which holds the molding sand in place while the pattern *c* is being drawn. The pattern in this case has been drawn about 6 inches, the power being supplied by a crane. Fig. 377 is a section view of the arrangement shown in Fig. 376. The mold plate *d* should either be bolted to a sunken plate to hold it down while the pattern is drawn, or bedded in concrete as was done in the equipment here shown.

Fig. 376. Pattern Being Drawn through Stripping Ring

Roll Pattern. The pattern is a hollow casting with four arms cast at each end, and finished all over, and no draft is to be allowed. The pattern construction will be the same as suggested for the first method of making this roll, but without the steel shaft.

Mold Plate. The mold-plate pattern is shown in Fig. 378. This illustration is upside down, and as only one casting is required, too much expense should not be put into its construction. The upper surface of the casting is to be finished and the recess for the dowel in the lower end of the pattern may be made by the machinist.

Stripping Ring. Fig. 379 illustrates the stripping ring *b*. A pattern for this part is to be furnished allowing finish on the under-

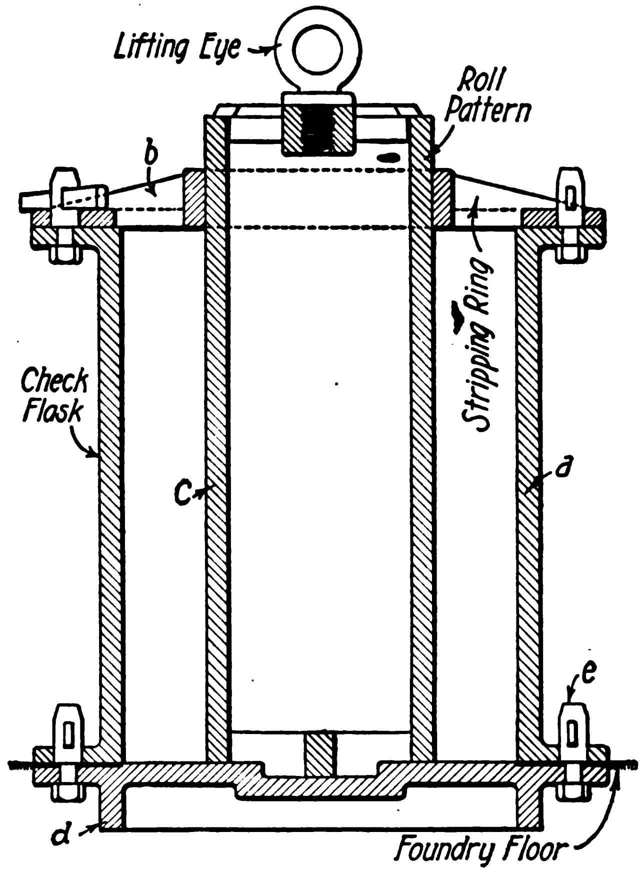


Fig. 377. Section of Cheek Mold on Mold Plate and Stripping Ring in Place

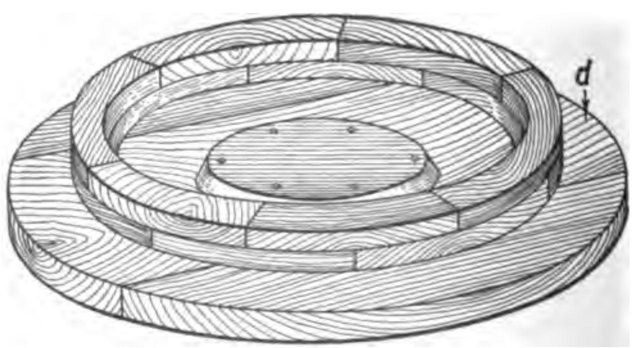


Fig. 378. Under Side of Pattern of Mold Plate

side and in the diameter of the hole. This ring should pass easily over the roll pattern, and, as soon as the pattern has been drawn, this ring is removed and the cheek is complete.

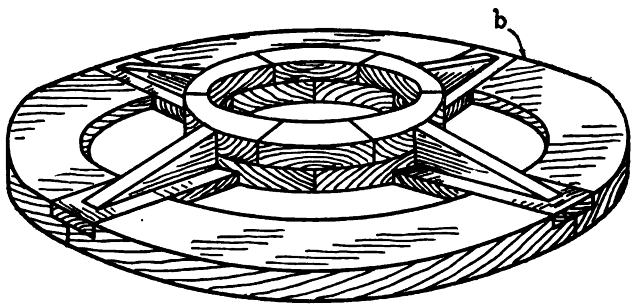


Fig. 379. Stripping Ring

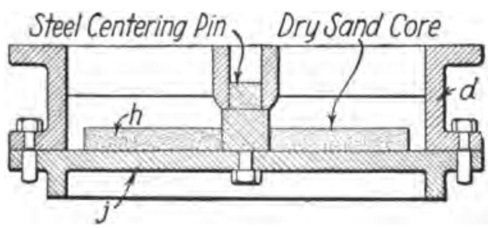


Fig. 380. Drag Flask on Mold Plate

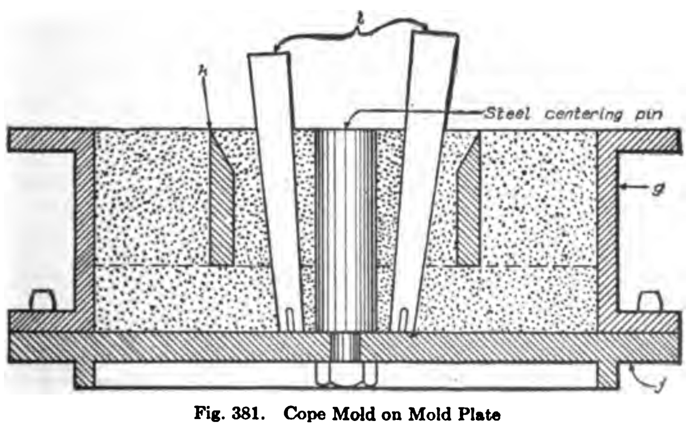


Fig. 381. Cope Mold on Mold Plate

Flask Construction. *Cheek.* The pattern for the flask will be molded by striking a green-sand core, lagging this to obtain the

thickness, and molding the lower flange with a dry-sand core, and the upper flange with loose segment pattern bedded in. Where iron pulley-rim or similar patterns are available, they may be used for the flask pattern without much expense. Allow a metal finish on the outside face of the flanges, and the inside of the flask for a depth of about ¾ inch is to be turned true, but no finish allowance need be made on this surface.

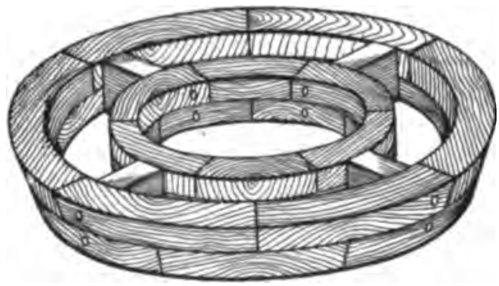


Fig. 382. Pattern for Centering Ring

Drag Flask. The drag flask will be of the same diameter as the cheek flask, but the depth need be only long enough to include the steel shaft. A hub is fitted at its center *i*, which will be machined to fit the finished end of the shaft. A shoulder is turned on the shaft, and the upper end of this hub is finished so as to locate the vertical height of the shaft. The drag flask is rammed on a cast-iron mold plate, as illustrated in Fig. 380. The flat disk dry-sand core is placed on this plate and rammed in, as illustrated in Figs. 380 and 384. For this core a wooden core box should be furnished.

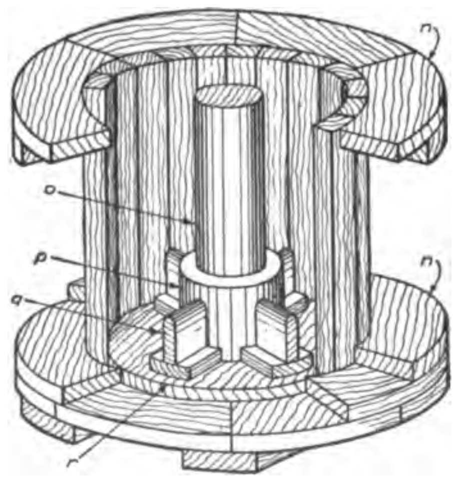


Fig. 383. Core Box for Arm Mold

Cope Flask. The cope flask, Fig. 381, is similar to the drag flask excepting the ring *k* and the radial bars. This ring should be large enough to provide space for the two sprues *l*. The upper inside edge of this ring is finished to a bevel to fit the centering ring *m*, Fig. 384. A sketch of the pattern for this ring is shown in Fig. 382.

The mold plate *j*, illustrated in Fig. 381, can be used for both drag and cope molds.

Inside Core. Fig. 383 illustrates the wooden core box for the inside of the mold. The rings *n* are made of two layers of segments glued and screwed together, and the walls of glued lagging firmly nailed and glued to the top and bottom rings. It should then be

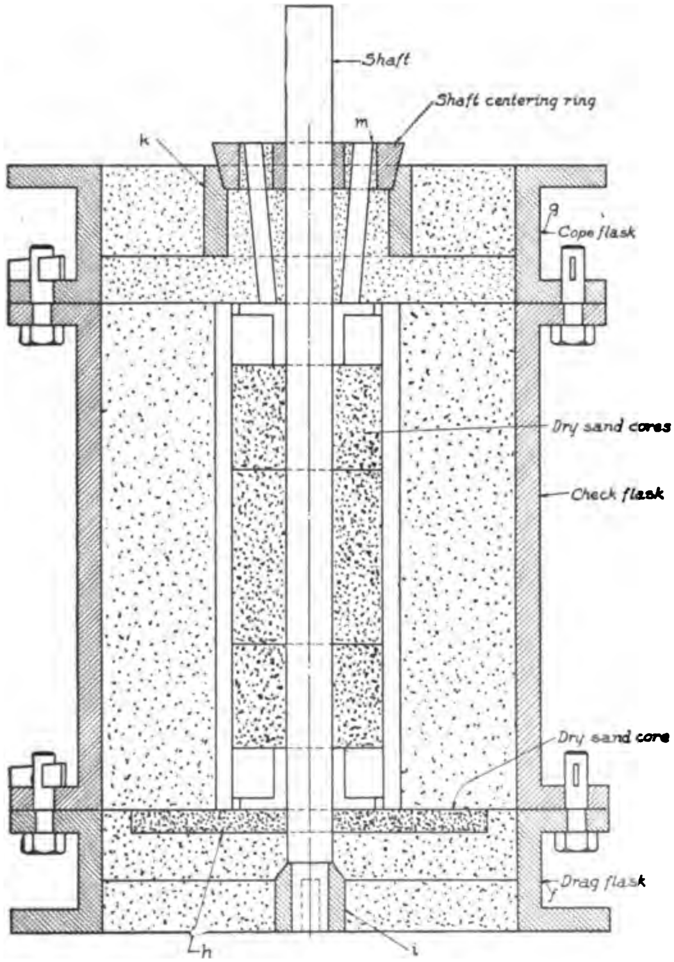


Fig. 384. Section of Complete Mold

mounted on a faceplate and turned true on the inside and on the ends. A very slight draft—about $\frac{1}{16}$ inch—should be allowed on the inside, and the height of the box will be 12 inches. The print *o*, hub *p*, and arm *q* patterns are fastened to the bottom board *r*;

the ends of the arms centering the outside of the core box with the print *o*. This print *o* should be at least $\frac{1}{16}$ inch larger than the steel shaft used. Two cores with the arm mold are required, and a center core without the arm mold. The length of this core is varied to produce rolls of different lengths. A bottom board is furnished without the arm and hub patterns, and the length is struck off to the height desired.

Fig. 384 illustrates a section of the complete mold.

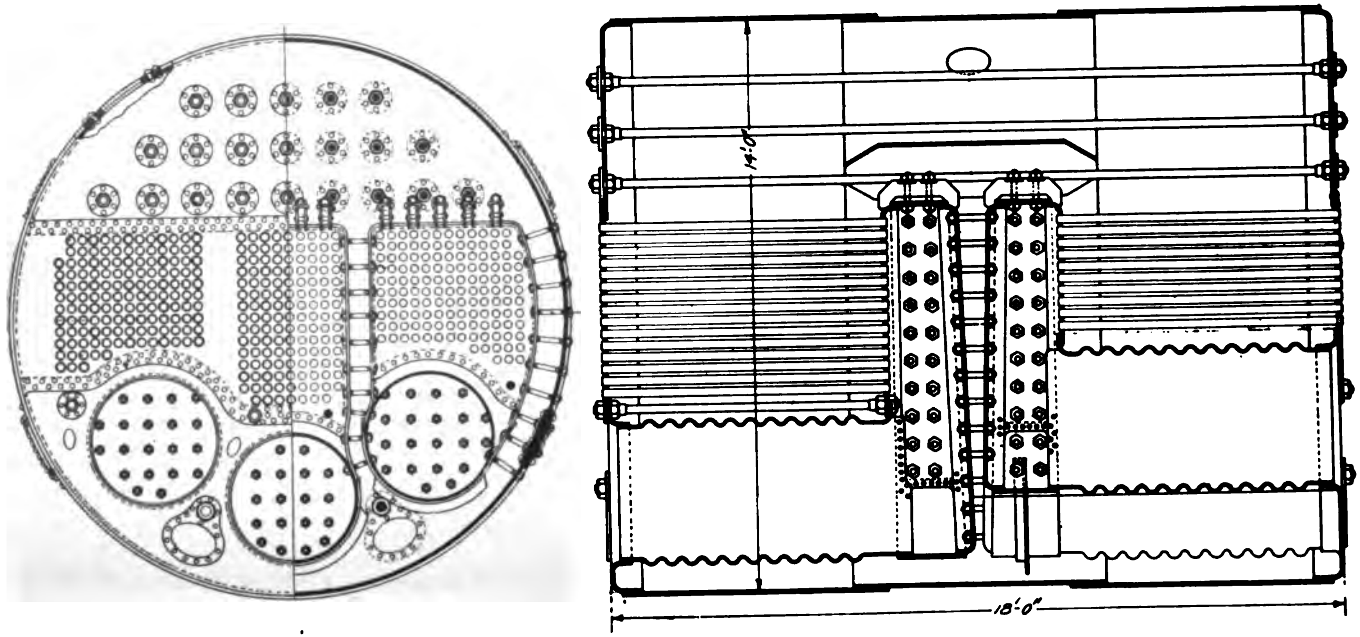
CONCLUSION

Resume. It may have been noticed that while great accuracy has been insisted upon, there have been no difficult problems of pattern making required in the adaptation of patterns to the molding machine.

Just as soon as the manufacturing requirements demand metal patterns mounted for machine molding, the bench work will be simplified.

The permanence of the master patterns is not a question, as they are usually molded soon after being completed, but these parts must be very accurately made.

There is plenty of opportunity for the display of mechanical ingenuity, but always consult the foundry experts regarding any new venture, for, as stated at the beginning, many patterns have been adapted to machine-molding that have proved to be failures when tried out in the foundry.



VERTICAL AND LONGITUDINAL SECTIONS OF 3-FLUE, DOUBLE-ENDED RETURN-TUBE BOILER

MECHANICAL DRAWING

PART I

The subject of mechanical drawing is of great interest and importance to all mechanics and engineers. Drawing is a method of showing graphically the minute details of machinery; it is the language by which the designer speaks to the workman; it is the most graphical way of placing ideas and calculation on record. A brief inspection of an accurate, well-executed working drawing gives a better idea of a machine than a lengthy written or verbal description. The better and more clearly a drawing is made, the more intelligently the workman can comprehend the ideas of the designer. Thorough training in this important subject is necessary to the success of every-one engaged in mechanical work.

The draftsman is dependent for his success, to a certain extent, upon the quality of the instruments and materials which he uses. As a beginner, he will find a cheap grade of instrument sufficient for his needs; but after he has become expert, it will be necessary for him to procure those of better construction and finish to enable him to do accurate work. It is a better plan to purchase the well-made instruments, if possible, at the start.

INSTRUMENTS AND MATERIALS

Drawing Paper. In selecting drawing paper, the first thing to be considered is the kind of paper most suitable for the proposed work. For shop drawings, a manila paper is frequently used on account of its toughness and strength, for these drawings are likely to be subjected to considerable hard usage. If a finished drawing is to be made, the best white drawing paper should be obtained, so that the drawing will not fade or become discolored with age. A good drawing paper should be strong; should have uniform thick-ness and surface; should stretch evenly and lie smoothly when stretched

or when ink or colors are used; should neither repel nor absorb liquids; and should allow considerable erasing without spoiling the surface. It is, of course, impossible to find all of these qualities in any one paper, as great strength cannot be combined with fine surface. However, a kind should be chosen which combines the greatest number of these qualities for the given work. Of the higher grades of papers, Whatman's are considered by far the best. This paper, either side of which may be used, is made in three grades: the *hot pressed*, which has a smooth surface and is especially adapted for pencil and very fine line drawing; the *cold pressed*, which is rougher than the hot pressed, has a finely grained surface, and is more suitable for water color drawing; and the *rough*, which is used for tinting. For general work, the cold pressed is the best as erasures do not show as plainly on it, but it does not take ink as well as the hot pressed.

Whatman's paper comes in sheets of standard sizes as follows:

Cap	13×17 inches	Imperial	22×30 inches
Demy	15×20 "	Atlas	26×34 "
Medium	17×11 "	Double Elephant . .	27×40 "
Royal	19×24 "	Antiquarian . . .	31×53 "
Super-Royal . . .	19×27 "		

The usual method of fastening paper to a drawing board is by means of thumb tacks or small one-ounce copper or iron tacks. First fasten the upper left-hand corner and then the lower right, pulling the paper taut. The other two corners are then fastened, and a sufficient number of tacks placed along the edges to make the paper lie smoothly. For very fine work, however, it is better to stretch the paper and glue it to the board. Turn up the edges of the paper all the way round—the margin being at least one inch—then moisten the surface of the paper by means of a sponge or soft cloth, and spread paste or glue on the turned-up edges. After removing all the surplus water on the paper, press the edges down on the board, commencing at one corner and stretching the paper *slightly*—if stretched too much it is liable to split in drying. Place the drawing board in a horizontal position until the paper is dry, when it will be found to be as smooth and tight as a drum head.

Drawing Board. The drawing board, Fig. 1, is usually made of well-seasoned and straight-grained soft pine, the grain running lengthwise of the board. Each end of the board is protected by a

side strip—1$\frac{3}{4}$ to 2 inches in width—whose edge is made perfectly straight for accuracy in using the T-square. Frequently the end

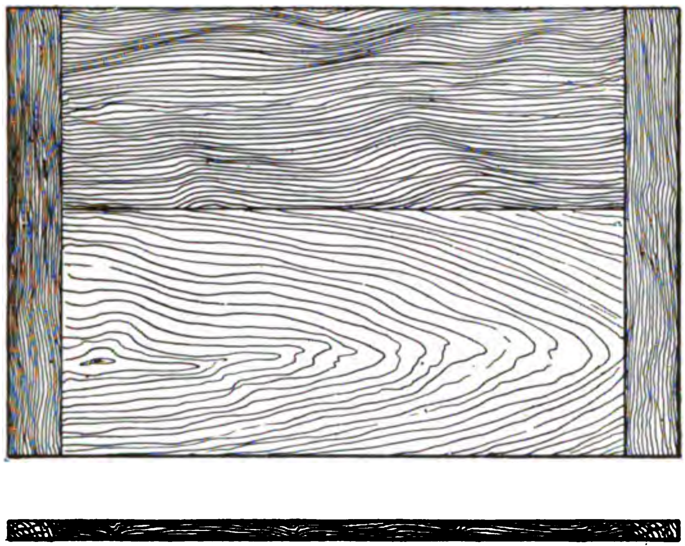


Fig. 1. Drawing Board

pieces are fastened by a glued matched joint, nails or screws. Two cleats on the bottom, extending the whole width of the board, will reduce the tendency to warp. Drawing boards are made in sizes to accommodate the sizes of paper in general use.

Thumb Tacks. Thumb tacks are used to fasten the paper to the drawing board. They are usually made of steel, pressed into shape—as in the cheaper grades—or with heads of German silver, the points being screwed and riveted to them. For most work, draftsmen use small one-ounce copper or iron tacks, as they are cheap and can be forced flush with the drawing-paper, thus offering no obstruction to the T-square.

Pencils. Lead pencils are graded according to their hardness, the degree of which is indicated by the letter H—as HH, 4H, 6H, etc. For general use a lead pencil of 5H or 6H should be used, although a softer 4H pencil is better for making letters, figures, and points. The hard lead pencil should be sharpened as shown in Fig. 2 so that in penciling a drawing the lines may be made very fine and light. The wood is cut away so that about $\frac{1}{4}$ or $\frac{1}{2}$ inch of lead

projects. The lead can then be sharpened to a chisel edge by rubbing it against a bit of sand paper or a fine file, and the corners slightly rounded. In drawing the lines the draftsman should place the chisel edge against the T-square or triangle, thus enabling him to draw a fine line exactly through a given point. If the drawing is not to be inked, but is made for tracing or for rough usage in the shop, a softer pencil, 3H or 4H, may be used, so as to make the lines somewhat thicker and heavier. The lead for compasses may also be sharpened to a point although some draftsmen prefer to use a chisel edge for the compasses as well as the pencil.

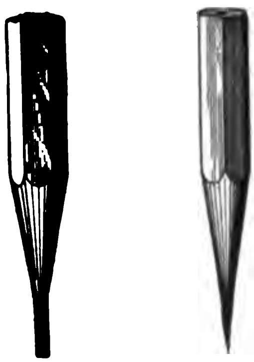


Fig. 2. Pencil Sharpened to a Chisel Point

In using a very hard lead pencil a light pressure should be used as otherwise the chisel edge will make a deep impression in the paper which cannot be erased.

Erasers. What little erasing is necessary in making drawings, should be done with a soft rubber. To avoid erasing the surrounding work some draftsmen use a card in which a slit is cut about 3 inches

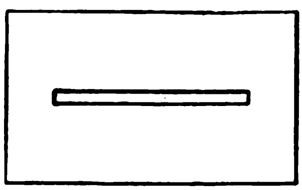


Fig. 3. Erasing Shield

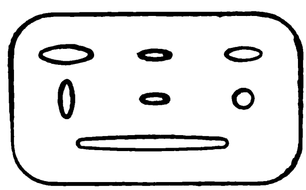


Fig. 4. Metal Erasing Shield

long and $\frac{1}{8}$ to $\frac{1}{4}$ inch wide, Fig. 3. An erasing shield of thin metal, Fig. 4, is also very convenient, especially in erasing letters. For cleaning drawings when they are completed, a sponge rubber or a preparation called "art gum" may be used, but in either case care should be taken not to make the lines dull by too hard rubbing.

T-Square. The T-square, which gets its name from its general shape, consists of a thin straight-edge, the *blade*, with a short piece, the *head*, fastened at right angles to it, Fig. 5. T-squares are usually made of wood, the pear and maple woods being used in the cheaper grades, and the harder woods, like mahogany, with protecting edges

of ebony or celluloid, Fig. 6, in the more expensive instruments. The head is designed to fit against the edge of the drawing board, allowing the blade to extend across the surface of the board. It is

Fig. 5. Common T-Square

desirable to have the blade of the T-square make a right angle with the head, but this is not absolutely necessary, if the head is always placed against the left-hand edge of the board, for the lines drawn

Fig. 6. Mahogany-Bound T-Square

with the T-square will then be referred to one edge of the board only, and if this edge is straight, the lines will be parallel to each other.

T-squares are sometimes provided with swiveled heads as it is frequently very convenient to draw lines parallel to each other which are not at right angles to the left-hand edge of the board. To use the T-square in drawing parallel horizontal lines,* place the head of the T-square in contact with the left-hand edge of the board, Fig. 7, and draw the pencil along the *upper edge* of the blade at each new position of the T-square. Only the upper edge should be used as the

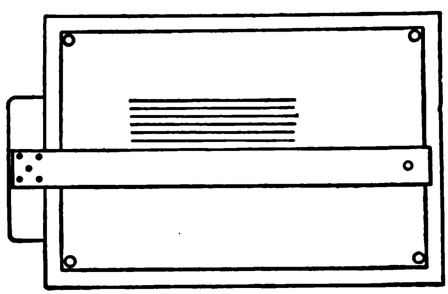


Fig. 7. Drawing Parallel Lines

* See Appendix.

two edges may not be exactly parallel and straight. In trimming drawings or cutting the paper from the board, always use the *lower edge* of the T-square so that the upper edge may not be made untrue.

For accurate work it is absolutely necessary that the upper edge of the T-square be exactly straight. To test the straightness of the edge two T-squares may be placed together as shown in Fig. 8. However, a lack of contact such as shown in the figure does not prove which edge is crooked, and for this determination a third blade must be used and tried with the two given T-squares successively.

Fig. 8. Testing the Edge of T-Square

Triangles. Triangles are made of various substances such as wood, rubber, celluloid, and steel. Wooden triangles are cheap but are likely to warp out of shape; rubber triangles are frequently used, and are, in general, satisfactory; celluloid triangles are extensively used on account of their transparency, which enables the draftsmen to see the work already done even when covered with the triangle.

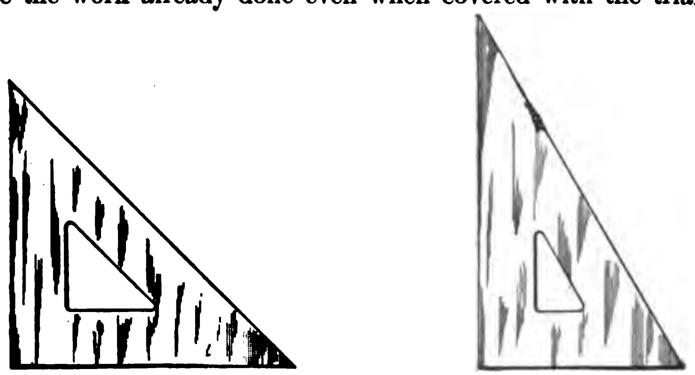


Fig. 9. 45° and 30° - 60° Triangles

In using a rubber or celluloid triangle take care that it lies perfectly flat and is hung up when not in use; when allowed to lie on the drawing board with a pencil or an eraser under one corner it will become warped in a short time, especially if the room is hot or the sun happens to strike the triangle.

Triangles from 6 to 8 inches on a side will be found convenient for most work, although there are many cases where a small triangle

measuring about 4 inches on a side will be found useful. Every draftsman should have at least two triangles, one having two angles of 45 degrees and one right angle; and the other having angles of 30, 60, and 90 degrees, respectively, Fig. 9.

The value of the triangle depends upon the accuracy of the angles and the straightness of the edges. To test the accuracy of

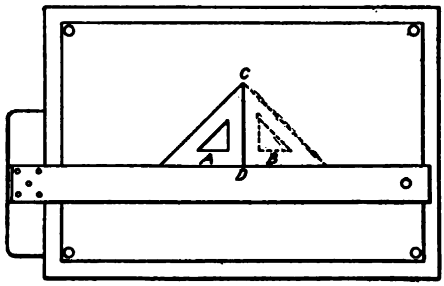


Fig. 10. Testing a Right Angle (45° Triangle)

the right angle of a triangle, place the triangle with the lower edge resting on the T-square in position *A*, Fig. 10. Now draw the line *C D*, which, if the triangle be true, will be perpendicular to the edge of the T-square. Transfer the triangle to position *B*, and if the right angle of the triangle is exactly 90 degrees the left-hand edge of the triangle will exactly coincide with the line *C D*.

To test the accuracy of the 45-degree angles place the triangle with the lower edge resting on the working edge of the T-square,

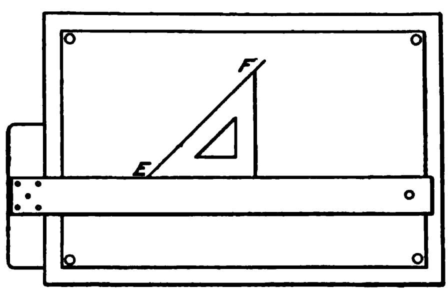


Fig. 11. Testing 45° Angle (45° Triangle)

and draw the line *E F*, Fig. 11. Now without moving the T-square place the triangle so that the other 45-degree angle is in the position occupied by the first. If the two 45-degree angles coincide they are accurate.

Triangles are used in drawing lines at right angles to the T-square, Fig. 12, and at an angle with the horizontal, Fig. 13. If it is desired to draw a line through the point *P*, Fig. 14, parallel to a given

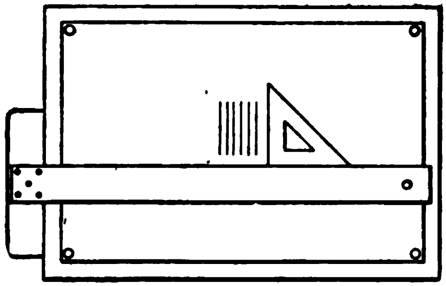


Fig. 12. Drawing Vertical Parallel Lines

line *E F*, two triangles should be used. First, place triangle *A* with one edge coinciding with the given line. Now take triangle *B* and place one of its edges in contact with the bottom edge of triangle *A*. Holding triangle *B* firmly with the left hand, slide triangle *A* to the right or to the left until its edge reaches the point *P*. The line *M N* may then be drawn passing through the point *P*. In place of the triangle *B* any straight-edge such as a T-square may be used.

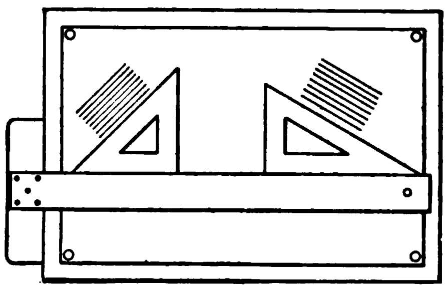


Fig. 13. Drawing Parallel Lines at an Angle with the Horizontal

A line may be drawn through a point, perpendicular to a given line by means of triangles as follows: Let *E F*, Fig. 15, be the given line, and let the point be *D*. Place the longest side of triangle *A* so that it coincides with the line *E F*. Place the other triangle (or any straight-edge) in the position of the triangle *B;* then holding *B* with the left hand, place the triangle *A* in the position *C*, so that the longest side passes through the point *D*. A line may then be drawn through the point *D* perpendicular to *E F*.

In previous figures it has been shown how lines may be drawn making angles of 30, 45, 60, and 90 degrees with the horizontal.

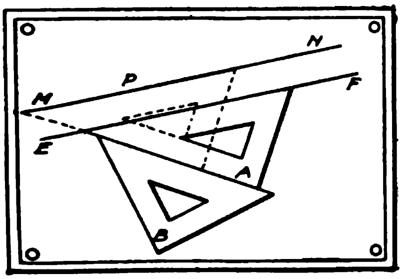


Fig. 14. Drawing a Line Parallel to a Given Line

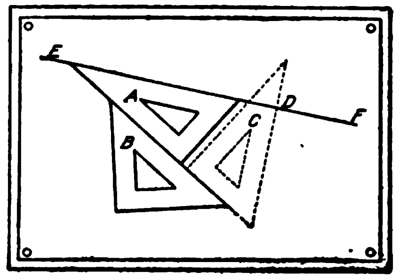


Fig. 15. Drawing a Line Perpendicular to a Given Line

It is possible to draw lines forming angles of 15 and 75 degrees by placing the triangles as shown in Fig. 16.

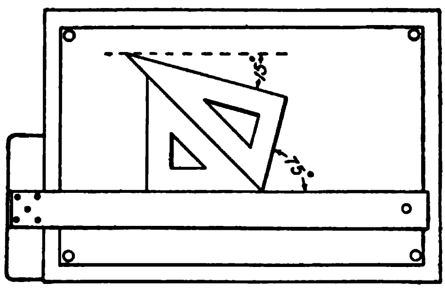


Fig. 16. Drawing Angle of 15° and 75°

By the use of the triangles and T-square almost any line may be drawn. Suppose it is desired to draw a rectangle having one side

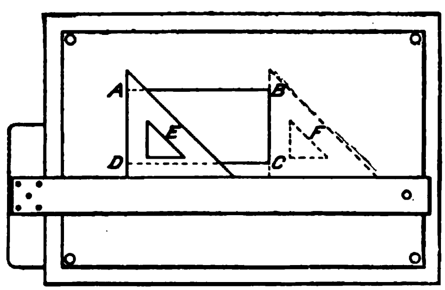


Fig. 17. Drawing a Rectangle with T-Square and Triangle

horizontal. First draw by means of the T-square the sides *A B* and *D C* horizontal and parallel, Fig. 17. Now place one of the

triangles on the T-square and in positions E and F draw the vertical lines $D A$ and $B C$.

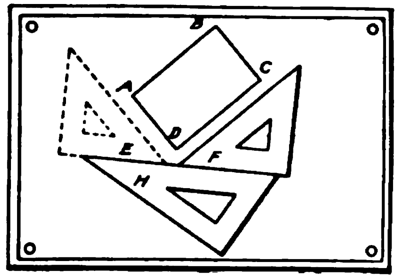


Fig. 18. Rectangle Drawn with Triangles

If the rectangle is to be drawn in some other position on the board, as shown in Fig. 18, place the 45-degree triangle F so that the longest edge is in the required direction of the side $D C$. Now, hold the triangle F in position and place another triangle in position H. By holding H in position and sliding triangle F, the sides $A B$ and $D C$ may be drawn. To draw the sides $A D$ and $B C$ change triangle F to position E and repeat the process.

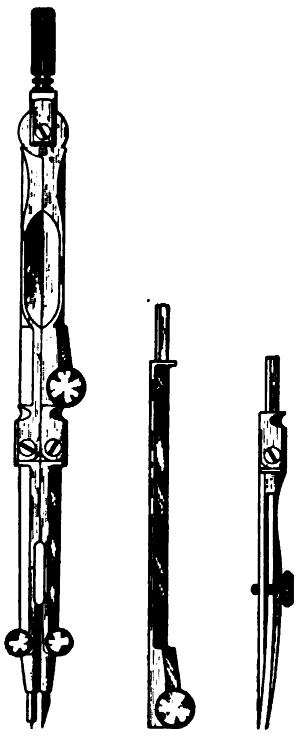


Fig. 19. Compasses and Attachments

Compasses. Compasses are used for drawing circles and arcs of circles. The cheaper class of instruments are made of brass, but they are unsatisfactory on account of the odor and the tendency to tarnish. The best material is German silver, as it does not soil the hands, has no odor, and is easy to keep clean. Aluminum instruments possess the advantage of lightness, but on account of the softness of the metal they do not wear well.

The compasses are made in the form shown in Fig. 19 and are provided with pencil and pen points. Fig. 20 shows the compass in position for drawing circles. One leg has a socket into which the shank of the pencil or pen mounting may be inserted. The other leg is fitted with a needle point which is placed at the center of the circle. In most instruments the needle point projects through a piece of round steel wire with a square shoulder at one or both ends.

In some instruments the joints are held in position by lock nuts,

made of thin disks of steel, with notches for using a wrench or forked key. Fig. 21 shows the detail of the joint of a high grade instrument. Both legs are alike at the joint, and two pivoted screws are inserted in the yoke. This permits ample movement of the legs, yet gives the proper stiffness. The flat surface of one leg is faced with steel, the other with German silver, so that the rubbing parts may be of different metals. Small set screws are used to prevent the pivoted screws from turning in the yoke. The contact surfaces of this joint are made circular to exclude dirt and to prevent rusting of the steel face.

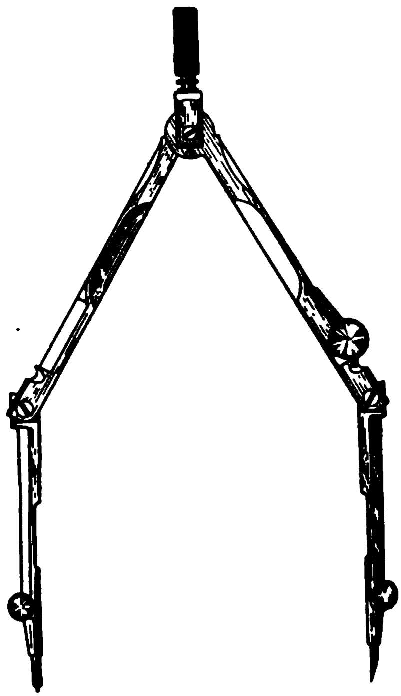


Fig. 20. Compasses Set for Drawing Circles

The details of the socket are shown in Fig. 22, Fig. 23, and Fig. 24; in some instruments the shank and socket are pentagonal, Fig. 22, the shank entering the socket loosely, and being held in place by means of the screw. Unless used very carefully this arrangement is not durable because the sharp corners soon wear, and the pressure on the set screw is not sufficient to hold the shank firmly in place.

In Fig. 23 is shown a round shank, the shank having a flat top, with a set screw to hold the shank in position. A still better form of socket is shown in Fig. 24, the hole being circular and tapered. The shank fits accurately into the split socket and is clamped by a screw on the side; it is held in perfect alignment by a small steel key.

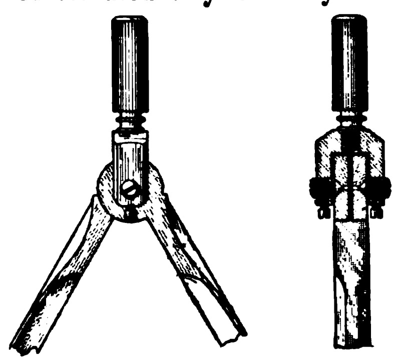


Fig. 21. Details of Compass Joint

Both legs of the compass are jointed in order that the lower part

of the legs may be perpendicular to the paper while drawing circles. In this way the needle point makes but a small hole in the paper, and both nibs of the pen will press equally on the paper. In penciling circles it is not as necessary that the pencil should be kept vertical;

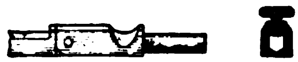


Fig. 22. Pentagonal Shank and Socket

Fig. 23. Circular Shank and Socket

it is a good plan, however, to learn to use them in this way both in penciling and inking. The compasses should be held loosely between the thumb and forefinger. If the needle point is sharp, as it should be, only a slight pressure will be required to keep it in place. While drawing the circle, incline the compasses slightly in the direction of revolution and press lightly on the pencil or pen.

Fig. 24. Circular Socket with Set Screw

In removing the pencil or pen attachment from the compass it should be pulled out straight in order to avoid enlarging the socket, and thus rendering the instrument inaccurate. For drawing large circles use the lengthening bar, Fig. 19, steadying the needle point with one hand and describing the circle with the other.

Dividers. Dividers, which are similar to compasses, are used to lay off distances on the drawing, either from a scale or from other parts of the drawing, Fig. 25. They are also used for dividing a line into equal parts. To do this turn the dividers in the opposite direction each time, *i. e.*, move the point alternately to the right and to the left. The points of the dividers should be very sharp so that the holes made in the paper will be small, thus assuring accurate spacing. Compasses may be used as dividers by substituting for the pencil or pen point an extra steel point, usually furnished with the instrument. In place of dividers many draftsmen use a *needle point*. The needle, with the eye-end broken off, is forced into a handle of soft pine, making a convenient instrument for marking line intersections and distances.

Fig. 25. Dividers

Bow Pen and Bow Pencil. Ordinary large compasses are too heavy and the leverage of the long leg is too great to allow small circles to be drawn accurately. For this reason the bow compasses, Figs. 26 and 27, should be used on all arcs and circles having a radius of less than $\frac{3}{4}$ inch; such as those which represent boiler tubes and bolt

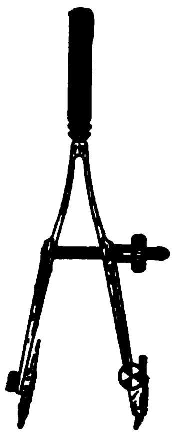


Fig. 26. Bow Pencil

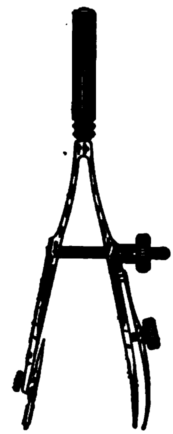


Fig. 27. Bow Pen

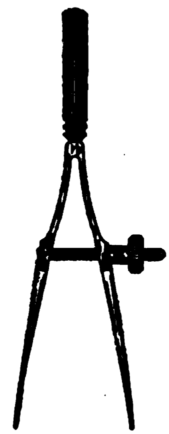


Fig. 28. Bow Divider

holes. When small circles are drawn, the needle point must be adjusted to the same length as the pen or pencil point. If a considerable change in radius is made, press the points together before turning the nut so as to prevent wear in the screw threads. The bow dividers, Fig. 28, replace the ordinary dividers in small work and have the advantage of a fixed adjustment.

Drawing Pen.* For drawing straight lines and curves that are not arcs of circles, the line pen—sometimes called the *ruling pen*—is

Fig. 29. Drawing Pen

used, Fig. 29. The distance between the pen points, which regulates the width of line to be drawn, is adjusted by the thumb screw, and the blades are given a slight curvature so that there will be a cavity for ink when the points are close together.

*See Appendix.

The pen should not be dipped in the ink but should be filled by means of a common steel pen or quill, to a height of about $\frac{1}{4}$ or $\frac{3}{8}$ inch; if too much ink is placed in the pen it is likely to drop out and spoil the drawing. Upon finishing the work wipe the pen with chamois or a soft cloth, because most liquid inks corrode the steel.

In using the pen, care should be taken that both blades bear equally on the paper, in order that the line may be smooth. The pen is usually inclined slightly in the direction in which the line is drawn and should touch the triangle or T-square lightly so as not to press the blades together and thereby change the width of the line; the pen must not be tipped outward, however, as the danger of blotting is greatly increased when the line is drawn so close to the guide.

Sharpening the Drawing Pen. When it is impossible to make a smooth line with the drawing pen, it should be sharpened. Screw the blades together and grind them to a parabolic shape by drawing the pen back and forth over a small, flat, close-grained oilstone. This process, of course, makes the blades dull but insures their being of the same length. Now separate the points slightly and rub one of them on the oilstone, keeping the pen at an angle of from 10° to 15° with the face of the stone, and giving it a slight twisting movement. This part of the operation requires great care as the shape of the ends must not be altered. After one point has become fairly sharp, grind the other in a similar manner, grinding always on the *outside* of the blades and removing the burr from the inside with leather or pine wood. Test the pen by filling with ink and drawing several lines. Unless the lines are smooth, the grinding must be continued.

Ink. India ink is always used for drawing as it makes a permanent black line; it is obtainable in solid stick or liquid form. The liquid form is much more convenient but contains acid which corrodes steel and makes it necessary to keep the pen perfectly clean.

To prepare the ink in stick form for use, put a little water in a saucer and place one end of the stick in it; then by a twisting motion grind enough ink to make the water black and slightly thickened. Now draw a heavy line on a sheet of paper and if after drying the line has a grayish appearance, more grinding is necessary. Wipe the stick dry after using to prevent crumbling. It is well to grind the ink in small quantities as it does not dissolve readily a second time; however, if covered it will keep for two or three days.

Scales. The scales used for obtaining measurements on drawings are made in several forms, the most convenient being the *flat*, with beveled edges, and the *triangular*. The scale is usually graduated for a distance of 12 inches. The triangular scale, Fig. 30, has six

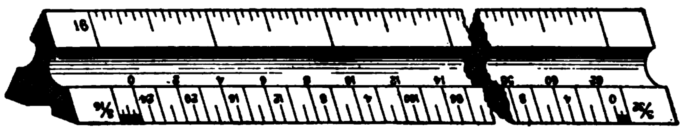


Fig. 30. Triangular Scale

surfaces for different graduations, and the scales are arranged so that the drawings may be made in any proportion to the actual size. For mechanical work, the common divisions are multiples of two; thus drawings are made full size, $\frac{1}{2}$ size, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, etc. If a drawing is $\frac{1}{4}$ size, 3 inches equals 1 foot, hence 3 inches is divided into 12 equal parts and each division represents one inch. If the smallest division on a scale represents $\frac{1}{16}$ inch, the scale is said to read to $\frac{1}{16}$ inch.

Scales are often divided into $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{30}$, $\frac{1}{40}$, etc., for architects and civil engineers, and for measuring indicator cards.

The scale should never be used as a substitute for the triangle or T-square in drawing lines.

Protractor. The protractor, an instrument used for laying off and measuring angles, is made of steel, brass, horn, or paper. When

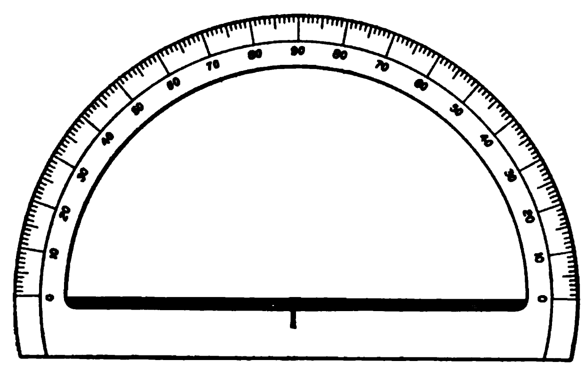


Fig. 31. Protractor

made of metal the central portion is cut out, Fig. 31, so that the draftsman may see the drawing. The outer edge is divided into degrees

and tenths of degrees. To lay off the required angle—use a very sharp, hard pencil in order that the measurements may be accurate—place the protractor so that the two zero marks are on the given line, produced, if necessary, and the center of the circle is at the point through which the desired line is to be drawn.

Irregular Curve. One of the conveniences of a draftsman's outfit is the *French* or *irregular curve*, which is used for drawing curves other than arcs of circles, with either pencil or line pen. This instrument, which is made of wood, hard rubber, or celluloid—celluloid being the best—is made in various shapes, one of the most common being shown in Fig. 32. Curves drawn with an irregular curve are called *free hand curves.*

To draw a curve through a series of located points find that position of the irregular curve that passes through three points,

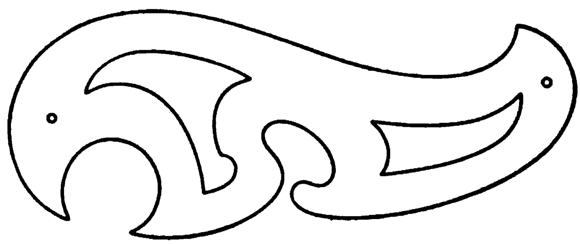


Fig. 32. Typical Irregular Curve

say, and draw the line through them, Fig. 33. Now shift the curve so as to include a part of the curve already drawn and two or three more points. Draw the curve through these points, continuing this process until the curve is completed. If, at each new setting, the line is not carried quite as far as the coincidence of the irregular curve would permit, a smoother curve will result. It frequently facilitates the work and improves its appearance to draw a pencil curve free hand through the points and then use the irregular curve, taking care that it always fits at least *three* points. In inking the curve, the blades of the pen must be kept tangent to the curve. For certain kinds of work, irregular curves of plastic metal are sometimes used to fit exceptionally erratic curves.

Beam Compasses. The ordinary compasses are suitable for drawing circles up to 8 or 10 inches diameter. For larger circles beam compasses are provided. The two parts called *channels*

which carry the pen or pencil and the needle point are clamped to a wooden beam at a distance equal to the radius of the circle. The

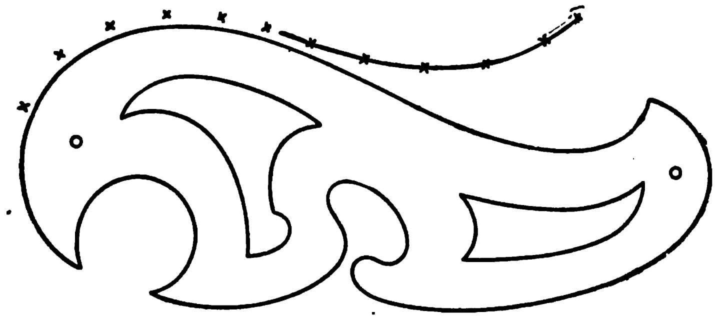


Fig. 33. Channels of Beam Compass

thumb nut underneath one of the channel pieces makes accurate adjustment possible.

LETTERING

No mechanical drawing is finished unless all headings, titles, and dimensions are lettered in plain, neat type. Many drawings are accurate, well-planned, and finely executed but do not present a good appearance because the draftsman did not think it worth while to letter carefully. Lettering requires time and patience especially for the beginner; and many think it a good plan to practice lettering before commencing drawing. Poor writing need not necessarily mean poor lettering, for good writers do not always letter well.

In making large letters for titles and headings it is often necessary to use drawing instruments and mechanical aids, but small letters, such as those used for dimensions, names of materials, dates, etc., **should be made free-hand.**

Forming. The student is apt to think that lettering is a form of mechanical drawing, that the use of the straight-edge is the principal operation, and that letters, forms, and the spaces between are to be figured out by measurement. On the contrary, lettering is design, and the draftsman so distributes the letters in the spaces arranged for them as to make a combination that will be pleasing to the eye. The requirements for a good design are simplicity and uniformity. These are acquired by accuracy in detail and by good judgment and taste, as no practical rules can be followed which will

invariably produce the same result. Letter forms are, to a certain extent, standard. The lettering for a title is usually done very carefully and accurately, while practically all of the other lettering on a drawing is done rapidly and in a simple style. To develop a letter use the same method of procedure as in drawing a straight line between two points. First, draw the guide lines rather carefully and then block out the general form of the letter by a series of short strokes of the pencil. Continue this method, straightening the lines and rounding the curves of the latter until its form is satisfactory.

Spacing. The spacing of the letters is very important and is best obtained by the unaided eye just as are the proportions of the letters. Care must be taken to allow a clear distance between letters, the space varying according to the combination. For instance, such letters as *A*, *V*, and *W* spread more at one part than at another and therefore do not fill the space completely. Of course, when the distance between letters is large any such irregularities will not be noticeable. The best method for obtaining good space values is by sketching in the letters roughly and then bringing them to a good appearance by correction and adjustment The first results are, of course, unsatisfactory, but after the eye and hand have become trained, great improvement will be noticed. A simple aid to this development will be found in the use of a piece of cardboard with the widths of the enclosing rectangles or parallelograms of the different letters marked on its edge, by which the spacing made by the eye may be checked.

Inking. In practical work most of the lettering is penciled in and then finished in ink. As faults in letters which may not be noticed in the penciled work stand out clearly after inking, it is not advisable to ink in the penciled letter accurately, but rather to improve upon it.

For lettering free-hand, use a pen that will make the full weight of line desired without much pressure, holding it squarely on the paper and directly in front. A new pen, which is apt to give too fine a line, may be remedied by scratching a little on a rough surface. If a pen is kept clean and all hardened ink removed so that the nibs are not spread, the pen will last a long time. A coarser pen must be used on rough than on smooth paper.

To remove a faulty line or a blot, let the ink dry thoroughly,

then with a sand rubber, erase the spot carefully, rubbing around it, as well. Clean the sand out of the surface with a pencil eraser and finally polish down with a piece of ivory or smooth wood. Pencil in the parts erased as if doing the work for the first time and again ink in, using special care, as the ink is more likely to spread on an erased surface than anywhere else.

Style. There are many styles of letters used by draftsmen, but almost any neat letter free from ornamentation is acceptable in regular practice. For titles, large Roman capitals are preferred, although Gothic and black letters also look well and are much easier to make. The vertical and inclined or italicized Gothic capitals shown in Fig. 34 and Fig. 35, are neat, plain, and easily made. This

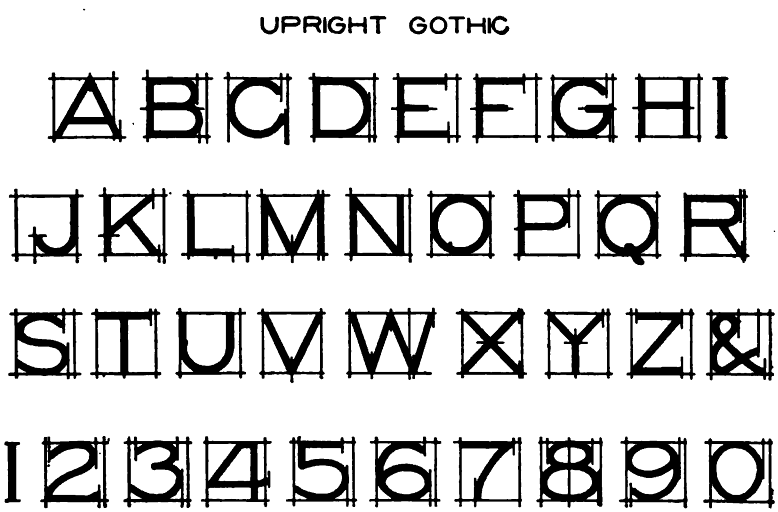


Fig. 34. Upright Gothic Capitals

latter style possesses the advantage over the vertical type in that a slight difference in inclination is not apparent.

The curves of the inclined Gothic letters such as those in *B*, *C*, *G*, *J*, etc., are somewhat difficult to make free-hand, especially if the letters are about one-half inch high. In the alphabet, Fig. 36, the letters are made almost wholly of straight lines, the corners only being curved.

The first few plates of this work will require no titles, the only lettering being the student's name, the date, and the plate number

which will be done in inclined Gothic capitals. Later the subject of lettering will again be taken up in connection with titles and headings for drawings which show the details of machines.

To make the inclined Gothic letters, first draw two parallel lines $\frac{3}{16}$ inch apart to mark the height for the letters of the date, name,

Fig. 35. Inclined Gothic Capitals

and plate number. This is the height to be used on all plates throughout this work, unless other directions are given. When two sizes of letters are used, the smaller should be about two-thirds as high as the larger. The inclination of the letters should be the same for all,

Fig. 36. Inclined Gothic Capitals— Straight Lines with Curved Corners

and as an aid to the beginner, light pencil lines may be drawn about $\frac{1}{4}$ inch apart, forming the proper angle with the parallel lines already drawn; this angle is usually about 70°, but if a 60° triangle is at hand, it may be used in connection with the T-square as shown in Fig. 38.

Capital letters such as *D, E, F, L, Z,* etc., should have their top and bottom lines coincide with the horizontal guide lines, as otherwise the work will look uneven. Letters, of which *C, G, O,* and *Q* are types, may be formed of curved or straight lines. If made of

curved lines, their height should be a little greater than the guide lines to prevent their appearing smaller than the other letters. In this work they may be made of straight lines with rounded corners as such letters are easily constructed and may be made of standard height.

To construct the letter *A*, use one of the 60° lines as a center line. Then from its intersection with the upper horizontal line drop a perpendicular to the lower guide line. Draw another line from the vertex meeting the lower guide line at the same distance on the other side of the center line. The cross line of the *A* should be a little below the center. The *V* is an inverted *A* without the cross line. For the letter *M*, the side lines should be parallel and about the same distance apart as the guide lines. The side lines of the *W* are *not* parallel but are farther apart at the top. The *J* is not quite as wide as such letters as *H*, *E*, *N*, *R*, etc. To make a *Y*, use the same spread as in making a *V* but let the diverging lines meet the center line a little below the middle.

The lower-case letters are shown in Fig. 37. In such letters

Fig. 37. Inclined Gothic Lower-Case Letters

as *m*, *n*, *r*, etc., make the corners slightly rounding. The letters *a*, *b*, *c*, *e*, *g*, *o*, *p*, *q*, should be full and rounding.

The style of the Arabic numerals is given in Fig. 36; Roman numerals are made of straight lines.

At first the copy should be followed closely and the letters drawn in pencil; the inclined guide lines may be used until the proper inclination becomes firmly fixed in mind when they should be abandoned. The horizontal lines, however, are used at all times by most draftsmen. After considerable practice has been had the letters may be constructed in ink without first using the pencil. When proficiency has been attained in the simple inclined Gothic capitals, the vertical, block and Roman alphabets should be studied.

PRELIMINARY LINE PROBLEMS

To lay out the paper for the plates of this work, place a sheet, *A B G F*, Fig. 38, on the drawing board 2 or 3 inches from the left-hand edge, called the *working edge.* If placed near the left-hand edge, the T-square and triangles can be used with greater firmness and the horizontal lines drawn with greater accuracy. In fastening the paper on the board, always true it up with the T-square according to the long edge of the sheet and use at least 4 thumb tacks —one at each corner. If the paper has a tendency to curl, 6 or 8

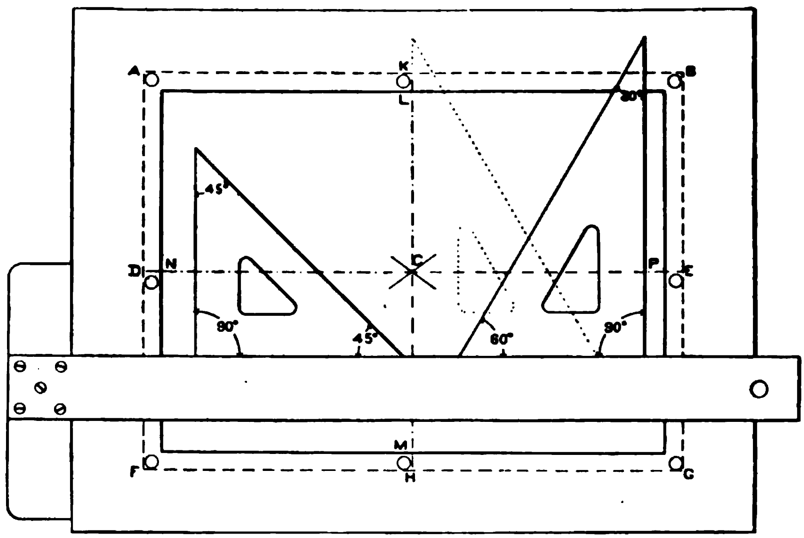


Fig. 38. Standard Lay-Out for Plates

tacks may be used placing them as shown in Fig. 38; many draftsmen prefer one-ounce tacks as they offer less obstruction to the T-square and triangles.

To find the center of the sheet place the T-square so that its upper edge coincides with the diagonal corners *A* and *G* and with the corners *F* and *B*, and draw short pencil lines intersecting at *C*. Now with the T-square draw through the point *C* the dot and dash line *D E*, and with the T-square and one of the triangles—shown dotted in Fig. 38—draw the dot and dash line *H C K*. It will probably be necessary to draw *CK* first and then by means of the T-square or triangle, produce (extend) *CK* to *H*. In this work always move

the pencil from left to right or from the bottom upward; except in certain cases.

After the center lines are drawn measure off 5 inches above and below the point C on the line $H\ C\ K$. These points L and M may be indicated by a light pencil mark or by a *slight* puncture by means of one of the points of the dividers. Now place the T-square against the left-hand edge of the board and draw horizontal pencil lines through L and M.

Measure off 7 inches to the left and right of C on the center line $D\ C\ E$ and draw pencil lines through these points N and P, perpendicular to DE. These lines form a rectangle 10 inches by 14 inches, in which all the exercises and figures are to be drawn. The lettering of the student's name and address, date, and plate number are to be placed *outside* of this rectangle in the ½-inch margin. In all cases lay out the plates in this manner and keep the center lines $D\ E$ and $K\ H$ as a basis for the various figures. Ink in the border line with a heavy line when the drawing is finished.

Penciling. In laying out the first few plates of this course the work is to be done in pencil and then inked in; later the subject of tracing the pencil drawings on tracing cloth and the process of making blue prints from these tracings will be taken up. Every beginner should practice with his instruments until he understands them thoroughly and can use them with accuracy and skill. To aid the beginner in this work, the first three plates of this course are practice plates; they do not involve any problems and none of the work is difficult. The student is strongly advised to draw these plates two or three times before making the one to be sent to us for correction. Diligent practice is necessary at first; especially on *Plate I* as it involves an exercise in lettering.

Inking. To ink a drawing well requires great care and some experience. The student should not attempt to ink in his work until he can make a clear-cut, straight line with ease. It is well to practice inking in straight pencil lines, rectangles, and triangles in order to improve the work on lines, corners, and intersections. These latter should be very definite, each line stopping at exactly the right point.

Before starting to ink in, adjust the pen by means of the thumb screw until a good clear line of the desired width is obtained, making frequent test lines, on a piece of material similar to that which is to

be used. Keep the pressure of the pen on the paper uniformly light, remembering that different weights of lines are not obtained by pressure as with the ordinary writing pen but only by adjusting the nibs of the pen. If the lines are ragged the pen should be put in order, according to the instructions already given. Sometimes when the ink does not flow regularly, moisten the end of the finger and touch the point of the pen. Care should be taken not to put too much ink in the pen, but on the other hand there must be enough to draw the next line as it is difficult to continue a line after re-filling the pen. The only way to draw fine lines well is to frequently clean and re-fill the pen. If the amount of ink in the pen is small it is quite likely to thicken in the point and cause clogging. When this occurs, draw a small strip of paper between the nibs to clean out the clogged ink.

When drawing, the pen should be held with the thumb screw out and should be inclined slightly in the direction in which it is moved. Be careful, however, not to incline it too much, as the best of pens when incorrectly held will produce poor lines. It is therefore advisable at the start to acquire the correct method of holding the pen. Do not press the sides of the pen point too heavily against the ruling edge as this will vary the width of the line; after a little practice the pen can be lightly and firmly brought in contact with the paper and ruling edge at the same time. The pen should be drawn from left to right, the hand being steadied by sliding it on the end of the little finger.

Always try to get into the easiest position when inking a line, even if it becomes necessary to walk around the drawing. The average draftsman prefers the standing position while inking as he can usually obtain much better results. Keep the ruling edge between the line and the body so that the pen will be drawn against the ruling edge, for if this is not done, the pen is liable to be pulled off at an angle, making a crooked line. Be careful after inking a line to draw the ruling edge toward the body away from the line in order to avoid blotting. Where lines meet at a point, always ink towards the point, being sure to allow one line to dry before inking another. Always ink in the top and left-hand lines first, gradually working down to the right, thus saving time that otherwise would be lost in waiting for the lines to dry. When the pen is set at the proper width, draw all the lines of that width before making a change. Never push

the pen backward over a line. If a good line is not drawn the first time, it is better to go over it again in the same direction, taking great care not to widen the original line.

Ink dries very quickly and should not be left in the pen on account of its corrosive effects. The celluloid triangles should be washed frequently in water and all ink spots removed.

In using the compass, bend both legs so that each will be perpendicular to the paper or cloth when the arc or circle is drawn. When the pen attachment is used special care must be exercised on this point for in no other way can the nibs of the pen be made to bear evenly on the surface. In drawing arcs, hold the cylindrical handle at the top of the compass loosely between the thumb and the forefinger and let it roll between the two during rotation; allow the compass to lean slightly in the direction of rotation, pressing down the pen point slightly but not the needle point. Be sure to fix the needle point firmly in its proper place on the paper before touching the pen to the paper, as otherwise a slip is likely to occur. In setting the needle down on any particular center, guide it with a finger of the left hand. Avoid making a noticeable hole in the paper.

Ink in the circumference of a circle with one continuous motion, giving an even pressure to the pen throughout the operation and stopping it sharply at the end of one revolution. Since straight lines can be more easily drawn tangent to curves than the reverse, it is always advisable to ink in all arcs or circles first. When a number of circles are to be drawn from one center, the smaller should be inked first while the center is in the best possible condition.

PLATE I

Penciling. To draw *Plate I*,* take a sheet of drawing paper at least 11 inches by 15 inches and fasten it to the drawing board as already explained. Find the center of the sheet and draw fine pencil lines to represent the lines *DE* and *HK* of Fig. 38. Also draw the border lines *L*, *M*, *N*, and *P*.

Now measure $\frac{3}{8}$ inch above and below the horizontal center line and, with the T-square, draw lines through these points. These lines will form the lower lines *DC* of Fig. 1 and Fig. 2 and the top lines *AB* of Fig. 3 and Fig. 4. Measure $\frac{3}{8}$ inch to the right and left

*Note Instructions in Appendix and Examination at End of Book.

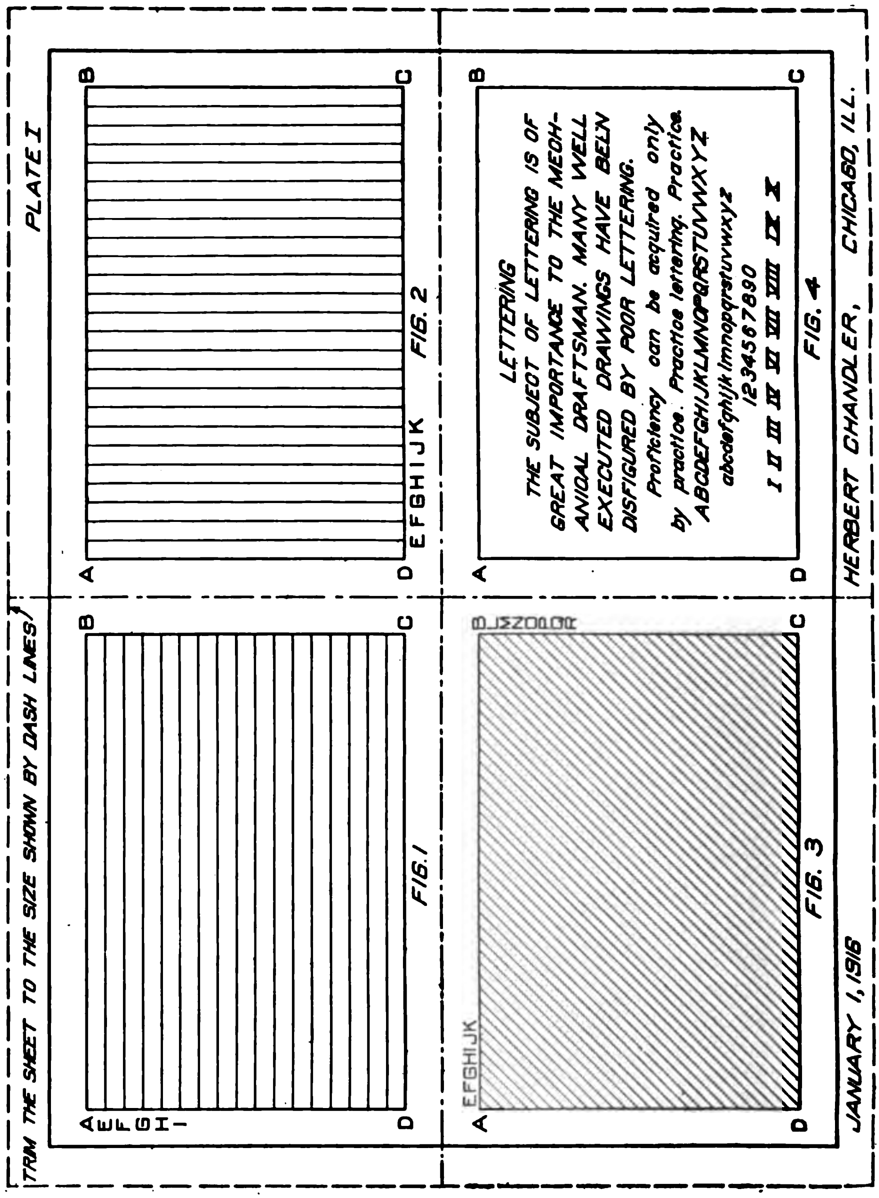


PLATE I
TRIM THE SHEET TO THE SIZE SHOWN BY DASH LINES!
A B C D
E F G H I J K
FIG. 1
FIG. 2
FIG. 3
FIG. 4
LETTERING
THE SUBJECT OF LETTERING IS OF GREAT IMPORTANCE TO THE MECHANICAL DRAFTSMAN. MANY WELL EXECUTED DRAWINGS HAVE BEEN DISFIGURED BY POOR LETTERING.
Proficiency can be acquired only by practice. Practice lettering. Practice.
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890
I II III IV V VI VII VIII IX X
HERBERT CHANDLER, CHICAGO, ILL.
JANUARY 1, 1916

of the vertical center line; and through these points, draw lines parallel to the center line. These lines should be drawn by placing the triangle on the T-square as shown in Fig. 38. The lines thus drawn, form the sides $B\ C$ of Fig. 1 and Fig. 3 and the sides $A\ D$ of Fig. 2 and Fig. 4. Next draw, with the T-square, the line $A\ B\ A\ B$ $4\frac{5}{8}$ inches above the horizontal center line, and the line $D\ C\ D\ C$ $4\frac{5}{8}$ inches below the horizontal center line. The rectangles of the four figures may now be completed by drawing vertical lines $6\frac{5}{8}$ inches on each side of the vertical center line; these rectangles are each $6\frac{1}{4}$ inches long and $4\frac{1}{4}$ inches wide.

Fig. 1. *Exercise with Line Pen and T-square.* Divide the line $A\ D$ into divisions each $\frac{1}{4}$ inch long, making a fine pencil point or *slight* puncture at each division such as E, F, G, H, I, etc. Now place the T-square with its head at the left-hand edge of the drawing board and through these points draw light pencil lines extending to the line $B\ C$. In drawing these lines the pencil point must pass *exactly* through the division marks so that the lines will be the same distance apart. Start each line in the line $A\ D$ and do not fall short of the line $B\ C$ or run over it. Accuracy and neatness in penciling insure an accurate drawing. Some beginners think that they can correct inaccuracies while inking; but experience soon teaches them that they cannot do so.

Fig. 2. *Exercise with Line Pen, T-square and Triangle.* Divide the lower line $D\ C$ of the rectangle into divisions each $\frac{1}{4}$ inch long and mark the points E, F, G, H, I, J, K, etc., as in Fig. 1. Place the T-square about as shown in Fig. 38, and either triangle in position with its 90-degree angle at the left. Now draw fine pencil lines from the line $D\ C$ to the line $A\ B$ passing through the points E, F, G, H, I, J, K, etc., keeping the T-square rigid and sliding the triangle toward the right.

Fig. 3. *Exercise with Line Pen T-square and 45-degree Triangle.* Lay off the distances $A\ E$, $B\ L$, etc., each $\frac{1}{4}$ inch long on $A\ B$ and $B\ C$, respectively. Place the T-square so that the upper edge will be below the line $D\ C$, and, with the 45-degree triangle, draw the diagonal lines through the points laid off. In drawing these lines move the pencil away from the body, *i. e.*, from $A\ D$ to $A\ B$ and from $D\ C$ to $B\ C$.

Fig. 4. *Exercise in Free-Hand Lettering.* Draw the center line $E\ F$, Fig. 39, and light pencil lines $Y\ Z$ and $T\ X$, $\frac{3}{8}$ inch from the

border lines. With the T-square, draw the line G, $\frac{1}{4}$ inch from the top line and the line H, $\frac{5}{32}$ inch below G. The word "*LETTERING*" is to be placed between these two lines. Draw the line I, $\frac{3}{16}$ inch below H, and space the lines included between I and K, $\frac{5}{32}$ inch apart.

The next style of letters to be discussed is lower-case letters. Draw the line L $\frac{3}{16}$ inch below K and to limit the height of the small letters draw a light line $\frac{1}{8}$ inch above L.

Make the space between L and M, $\frac{5}{32}$ inch and draw M and N in the same manner as K and L. Now draw O, $\frac{3}{16}$ inch below N,

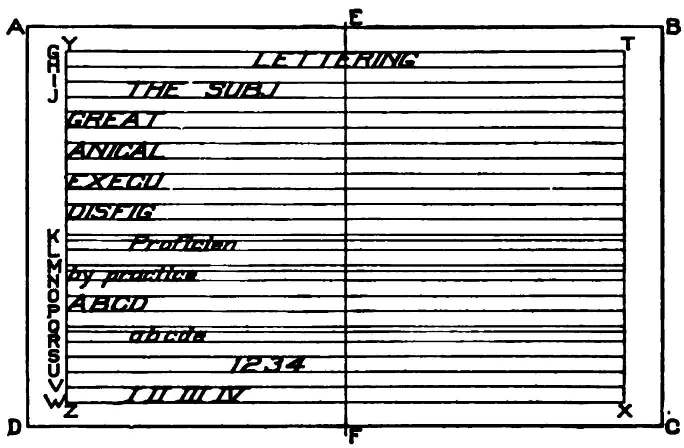


Fig. 39. Sample Lettering Plate—Fig. 4., Plate I

P, $\frac{5}{32}$ inch below O, and Q, $\frac{5}{32}$ inch below P. Space Q and R as K and L, and draw S, U, V, and W, $\frac{5}{32}$ inch apart.

The center line is a great aid in centering the word "*LETTERING*," the alphabets, numerals, etc. Indent the words "*THE*" and "*Proficiency*" about $\frac{3}{8}$ inch, as they are the first words of paragraphs. To draw the guide lines, mark off distances of $\frac{1}{4}$ inch on any line such as J and with the 60-degree triangle draw light pencil lines cutting the parallel lines. Sketch the letters in pencil making the width of the ordinary letters such as E, F, H, N, R, etc., about $\frac{3}{4}$ their height. Letters like A, M, and W, are wider. The space between the letters depends upon the draftsman's taste, but the beginner should remember that letters next to an A or an L should be placed nearer to them than to letters whose sides are parallel; for

instance there should be more space between an *N* and *E* than between an *E* and *H*. Similarly a greater space should be left on either side of an *I*. On account of the space above the lower line of the *L*, a letter following an *L* should be close to it. If a *T* follows a *T* or an *L* follows an *L* place them near together. In all lettering place the letters so that the general effect is pleasing. After the four figures are completed, pencil in the lettering for name, address, and date. With the T-square draw a pencil line $\frac{5}{32}$ inch above the top border line at the right-hand end, and about 3 inches long. At a distance of $\frac{5}{32}$ inch above this line draw another line of about the same length. These are the guide lines for the word *Plate I*. Pencil the letters free-hand using the 60-degree guide lines if desired.

Draw in a similar manner the guide lines of the date, name, and address in the lower margin, the date of completing the drawing placed under Fig. 3, and the name and address at the right, under Fig. 4. The street address is unnecessary. It is a good plan to draw lines $\frac{5}{32}$ inch apart on a separate sheet of paper and pencil the letters in order to know just how much space each word will require. The insertion of the words "Fig. 1," "Fig. 2," etc., is optional with the student, but it is advised that he do this extra lettering for the practice as well as for convenience in reference. First draw with the T-square two parallel lines $\frac{5}{32}$ inch apart under each exercise, the lower line being $\frac{1}{16}$ inch above the horizontal center line or above the lower border line.

Inking. After all of the penciling of *Plate I* has been completed the exercises should be inked. Before doing this, however, see that the pen is in proper condition, and after filling try it on a separate piece of paper in order that the proper width of line may be drawn. In the first work where no shading is done, use a firm, distinct line. The beginner should avoid the extremes; a very light line makes the drawing appear weak and indistinct, while a very heavy line detracts from its artistic appearance.

Ink in all the horizontal lines of Fig. 1 first, moving the T-square from *A* to *D*, and take great care to start and stop the lines exactly on the vertical boundary lines. It is necessary to use both triangle and T-square for inking *A D* and *B C*. In inking Fig. 2 and Fig. 3, follow the same directions as for penciling, inking in the vertical and oblique lines first and then the border lines. Ink the border lines

of Fig. 4 first and then the border lines of the plate, making the latter very heavy and the intersections accurate. The lettering in Fig. 4 should be done free-hand, using a steel pen not finer than a Gillott 404. Now ink in the four figure numbers, plate number, date, and name, also free-hand, and then erase the pencil lines. **In the finished drawing there should be no center lines, construction lines, or letters other than those in the name, date, etc.**

Cut the sheet 11" × 15", the dash line outside the border line of *Plate I* indicating the edge.

PLATE II

Penciling. The horizontal and vertical center lines and the border lines for *Plate II* are laid out in the same manner as were those of *Plate I*. To draw the squares for the six figures, proceed as follows:

Measure off two inches on either side of the vertical center line and draw light pencil lines through these points parallel to the vertical center line. These lines will form the sides *A D* and *B C* of Fig. 2 and Fig. 5. Parallel to these lines and at a distance of ½ inch draw similar lines to form the sides *B C* of Fig. 1 and Fig. 4 and *A D* of Fig. 3 and Fig. 6. The vertical sides *A D* of Fig. 1 and Fig. 4 and *B C* of Fig. 3 and Fig. 6 are formed by drawing lines perpendicular to the horizontal center line at a distance of 6½ inches from the center.

Complete the figures by laying off lines ½ inch and 4½ inches above and below the horizontal center line respectively, thus forming six 4-inch squares.

In drawing Fig. 1, divide *A D* and *A B* into 4 equal parts, then draw horizontal lines through *E*, *F*, and *G* and vertical lines through *L*, *M*, and *N*. Draw lines from *A* and *B* to the intersection *O* of lines *E* and *M*, and from *A* and *D* to the intersection *P* of lines *F* and *L*. Similarly draw *D J*, *J C*, *C I*, and *I B*. Also connect the points *O*, *P*, *J*, and *I*, thus forming a square. The four diamond-shaped areas are formed by drawing lines from the middle points of *A D*, *A B*, *B C*, and *D C* to the middle points of lines *A P*, *A O*, *O B*, *I B*, etc., as shown in Fig. 1.

Fig. 2 is an exercise of straight lines. Divide *A D* and *A B* into four equal parts and draw horizontal and vertical lines as in Fig. 1. Now divide these dimensions, *A L*, *M N*, etc., and *E F*,

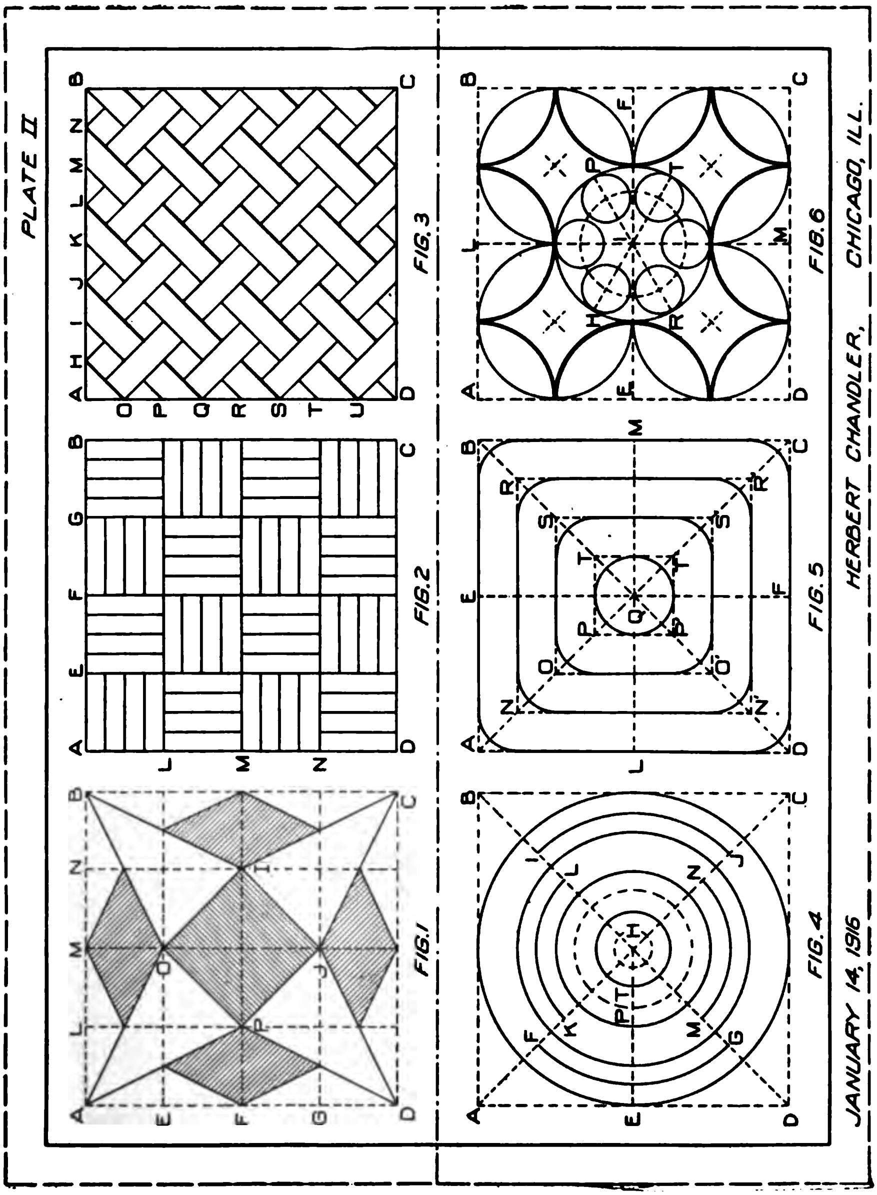


PLATE II
FIG. 1
FIG. 2
FIG. 3
FIG. 4
FIG. 5
FIG. 6
HERBERT CHANDLER, CHICAGO, ILL.
JANUARY 14, 1916

G B, etc., into four equal parts—each ¼ inch—and draw light pencil lines with the T-square and triangle as shown.

In Fig. 3, divide *A D* and *A B* into eight equal parts, and through the points *O*, *P*, *Q*, *H*, *I*, *J*, etc., draw horizontal and vertical lines. Now draw lines connecting *O* and *H*, *P* and *I*, *Q* and *J*, etc. As these lines form an angle of 45 degrees with the horizontal, a 45-degree triangle may be used. Similarly from each one of the given points on *A B* and *A D*, draw lines at an angle of 45 degrees to *B C* and *D C* respectively.

Fig. 4 is drawn with the compasses. Draw the diagonals *A C* and *D B*, and with the T-square draw the line *E H*. Now mark off on *E H* distances of ¼ inch, and with *H* as a center describe, by means of the compasses, circles having radii respectively 2 inches. 1½ inches, 1 inch, ¾ inch, ½ inch, and ¼ inch. Similarly with *H* as a center and a radius of 1¾ inches and 1¼ inches respectively draw the arcs *F G* and *I J* and *K L* and *M N*, being careful to end the arcs in the diagonals.

Fig. 5 is an exercise with the line pen and compasses. Draw the diagonals *A C* and *D B*, the horizontal line *L M* and the vertical line *E F* passing through the center *Q*. Mark off distances of ½ inch on *L M* and *E F* and complete the squares *N R R′ N′*, etc. With the bow pencil adjusted so that the distance between the pencil point and the needle point is ½ inch, draw arcs having centers at the corners of the inner squares. The arc whose center is *N* will be tangent to the lines *A L* and *A E* and the arc whose center is *O* will be tangent to *N N′* and *N R*. Since the smallest square has 1 inch sides, the ½-inch arcs drawn with *Q* as a center will form a circle.

In Fig. 6, draw the center lines *E F* and *L M*, and find the centers of the four squares thus formed. Through the center *I* draw the construction lines *H I T* and *R I P* forming angles of 30 degrees with *EF*. Now adjust the compasses to draw circles having a radius of one inch, and with *I* as a center, draw the circle *H P T R*. With the same radius draw the arcs with centers at *A*, *B*, *C*, and *D*, and also draw the semicircles with centers at *L*, *F*, *M*, and *E*. Now draw the arcs as shown having centers at the centers of the four squares. To locate the centers of the six small circles within the circle *H P T R*, draw a circle with a radius of $\frac{11}{16}$ inch and having the center in *I*. The small circles each have a radius of $\frac{5}{16}$ inch.

Inking. In *Plate II* ink in only the lines shown *full* in the specimen plate. First ink the star and then the square and diamonds. As this is an exercise for practice, the cross-hatching should be done *without* measuring the distance between the lines and without the aid of any cross-hatching device. The lines should be about $\frac{1}{16}$ inch apart. After inking in the plate all construction lines should be erased.

In inking Fig. 2 first ink the principal horizontal and vertical lines and then very carefully ink in the short lines. Make these lines all of the same width.

Fig. 3 is drawn entirely with the 45-degree triangle. In inking the oblique lines make $P\,I$, $R\,K$, $T\,M$, etc., of the usual width, while the alternate lines $O\,H$, $Q\,J$, $S\,L$, etc., should be somewhat heavier. All of the lines which slope in the opposite direction are light. Now ink in the border lines and erase all other horizontal and vertical lines.

In inking Fig. 4 use only the compasses, adjusting the legs so that the pen will always be perpendicular to the paper. In inking the arcs, see that the pen stops *exactly* at the diagonals. The inner circle and the next but one should be dotted as shown in the specimen plate. After inking the circles and arcs erase the construction lines that are without the outer circles, leaving in *pencil* the diagonals inside the circles.

In Fig. 5 *draw all arcs first* and then the straight lines meeting these arcs, as it is much easier to make a straight line meet an arc or tangent to it, than the reverse. Leave all construction lines in pencil. This exercise is difficult, and as in all mechanical and machine drawing, arcs and tangents are frequently used, the beginner is advised to draw this exercise several times.

Fig. 6 is an exercise with compasses. If the laying out has been accurately done in pencil, the inked arcs will be tangent to each other and the finished exercise will have a good appearance. If, however, the distances were not accurately measured and the lines carefully drawn, the inked arcs will not be tangent. The arcs whose centers are L, F, M, and E, and A, B, C, and D should be heavier than the rest. The small circles may be drawn with the bow pen. After inking the arcs all construction lines should be erased.

Finally ink in the figure numbers, the border lines of the plate, name, address, and plate number as in *Plate I.*

PLATE III

Penciling. *Plate III* should be laid out in the same manner as *Plate II*, that is, for size and border lines. In laying out the sixteen rectangles, however, the space between the center lines and rectangles must in every case be made ½ inch. Each rectangle is to be filled in with what is called *section lining*, illustrating the material of which the object is composed, and, therefore, differing accordingly. The conventions here shown are standard, and some of them will be used by the student in later work in Machine Drawing. Familiarity with them is of value to any draftsman. In drawing section lines of this character, the closeness of the lines should be governed by the area being sectioned. For large areas use a rather wide spacing; for small areas use a narrow spacing. In showing a section of any machine, the different parts are distinguished by altering the slope of the section lines, whether of the same material or not.

Draw the sixteen figures in full and then draw the border lines of the plate. Make the lettering conform to that in *Plate I* and *Plate II*.

Inking. After all the penciling of *Plate III* has been completed, the exercise should be inked, including the titles.

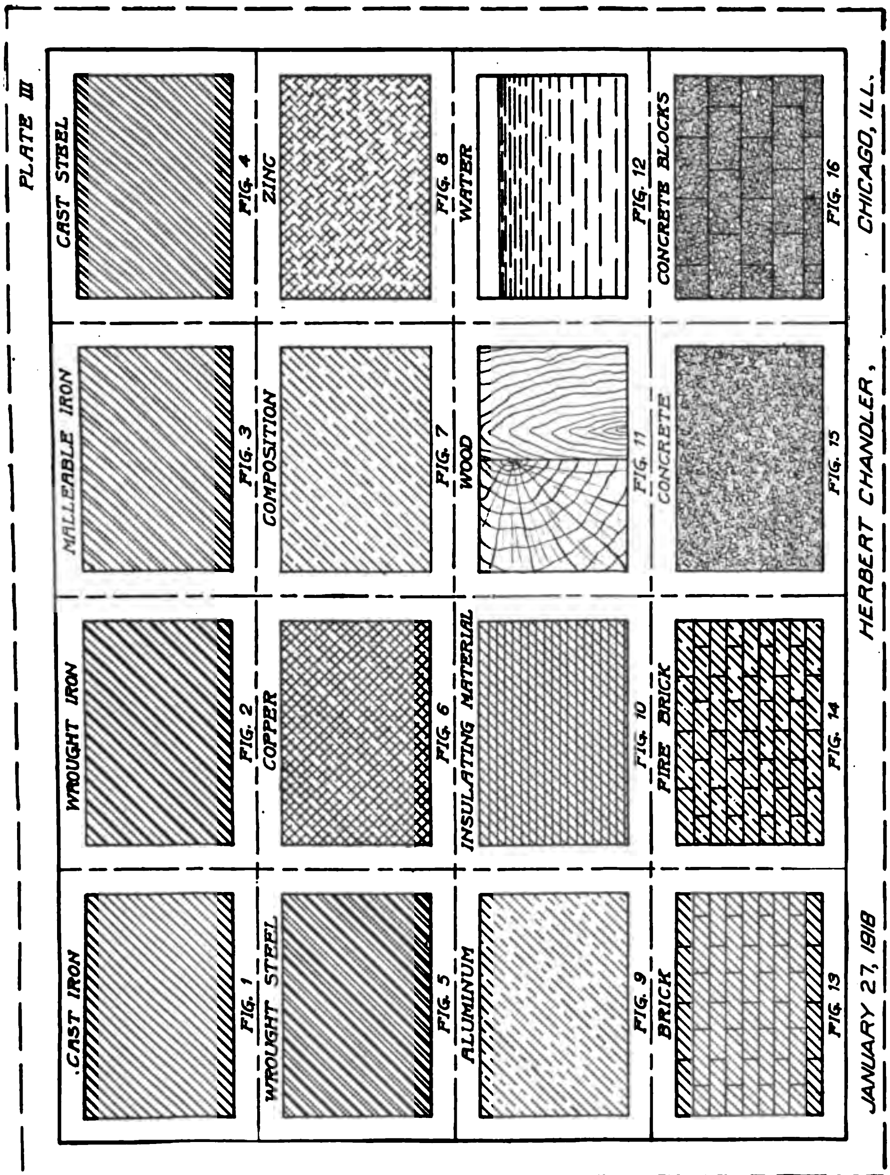


PLATE III
CAST IRON
FIG. 1
WROUGHT STEEL
FIG. 5
ALUMINUM
FIG. 9
BRICK
FIG. 13
WROUGHT IRON
FIG. 2
COPPER
FIG. 6
INSULATING MATERIAL
FIG. 10
FIRE BRICK
FIG. 14
MALLEABLE IRON
FIG. 3
COMPOSITION
FIG. 7
WOOD
FIG. 11
CONCRETE
FIG. 15
CAST STEEL
FIG. 4
ZINC
FIG. 8
WATER
FIG. 12
CONCRETE BLOCKS
FIG. 16
JANUARY 27, 1918
HERBERT CHANDLER,
CHICAGO, ILL.

APPENDIX

HOW TO HOLD DRAWING INSTRUMENTS

Position of Hand and Instruments Important. To the student who is just starting out with his drawing work, the position in which he holds his instruments and the free and easy posture of his hands are very important. The following studies should be used in connection with the instructions given in the forepart of this book and

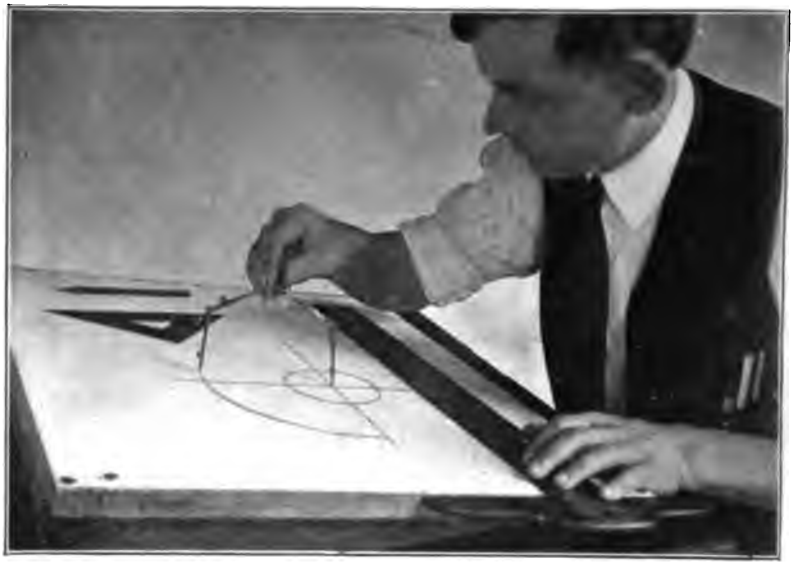
Position of Right Line Pen against T-Square or Triangle

wherever references have been given to the appendix it is expected that the student will study these plates so as to receive helpful suggestions in his work. In developing skill in Mechanical Drawing, practice is the only method of achieving results after the fundamental principles have been mastered. A very useful collection of "DONT'S" is given herewith and these will bear very close study.

Drawing Pencil Line with T-Square and Triangle

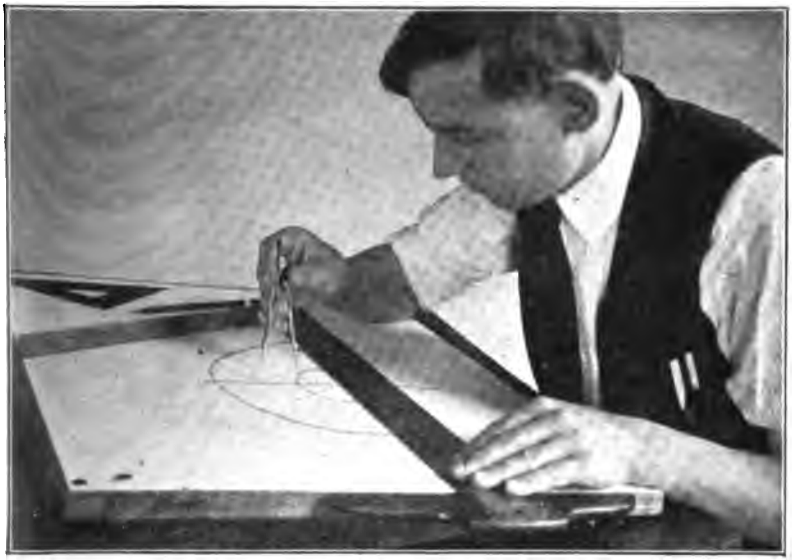
Inking a Line with Pen and T-Square

Drawing Small Circle with the Compass



Drawing Large Circle with Compass with Bent Legs

Drawing Very Large Circle with Spread Compass and Lengthening Bar



Adjusting Dividers with One Hand. Note Second and Third Fingers between Legs

"DONT'S IN DRAFTING WORK

Don't fold a drawing.
Don't stick the dividers into the drawing board.
Don't use the dividers as picks.
Don't use the scale to rule lines.
Don't fail to clean the table, board, and instruments when beginning work.
Don't draw the lower edge of the T-square.
Don't cut the sheets of drawing paper with the upper edge of the T-square and a knife; use the lower edge.
Don't put the end of a pencil in the mouth.
Don't oil the compass joints.
Don't put away the instruments without cleaning, especially pens.
Don't use the cheapest materials.
Don't use the T-square as a hammer.
Don't screw up the nibs of the pen too tight.
Don't use a blotter on lines that have been inked.
Don't run the pen or pencil backward over a line.
Don't fill a pen over a drawing.

Don't dilute drawing ink with water; if too thick throw it away.
Don't leave a bottle of ink uncorked.
Don't put away bow instruments screwed up tight; open to the size to fit place in case.
Don't scrub a finished drawing too hard; it takes out the life.

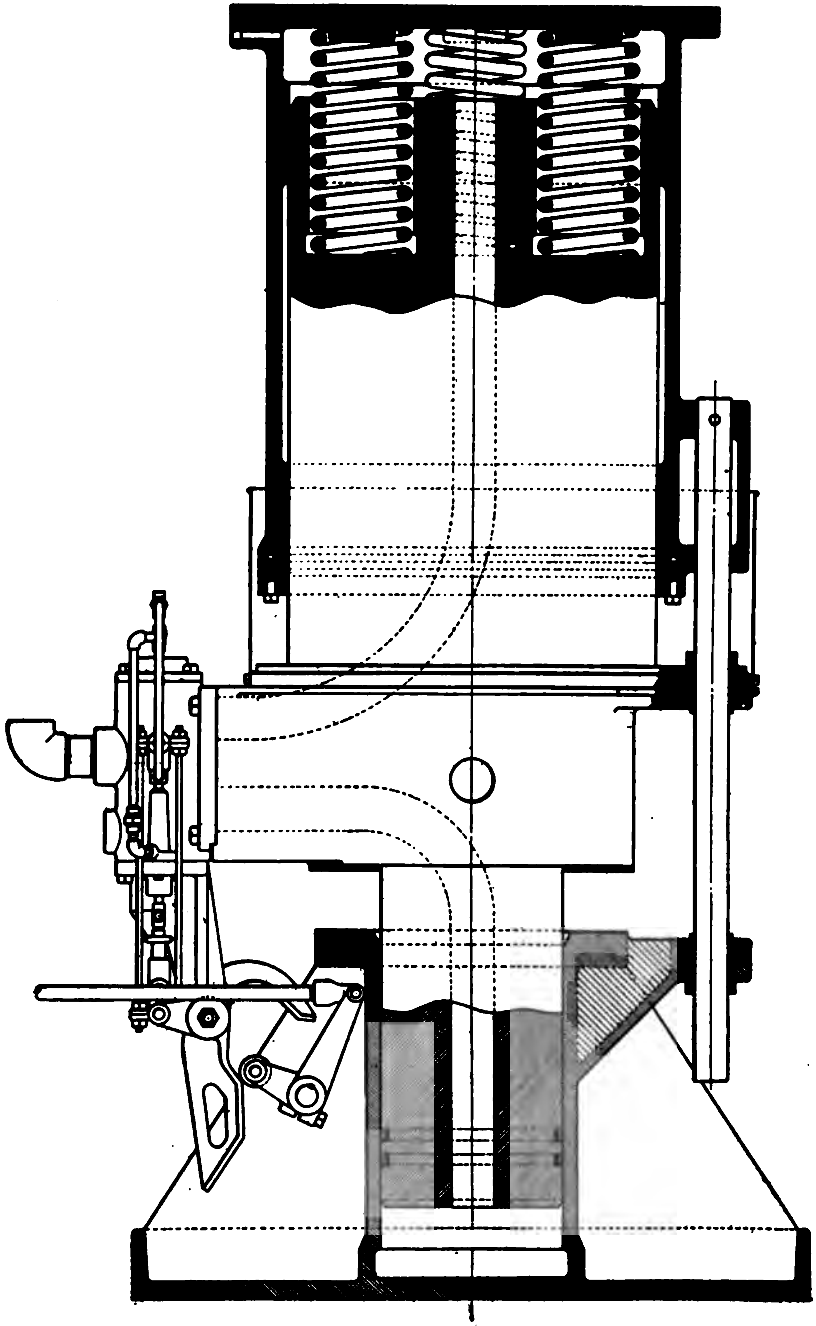
EXAMINATION PLATES

Drawing *Plates I* to *III* inclusive constitute the Examination for this Instruction Paper. The student should draw these Plates in ink and send them to the School for correction and criticism.

The vertical letters are merely for explanation and should not be placed upon the plates sent us. The dot and dash center lines and the lines used for spacing the sheet should not be inked. The date, student's name and address, and the plate number should be lettered on each plate in inclined Gothic capitals.

IMPORTANT

Any student so desiring may, on completion of Plate I, send it in to the School for correction and criticism as a Practice Plate. Before going to the labor of drawing all three plates, he will thus have the benefit of his Instructor's suggestions for improvement, and can take advantage of these in re-drawing *Plate I*, and in drawing *Plates II* and *III* for the regular examination.



SECTION OF SHOCKLESS JARRING MACHINE
Courtesy of Tabor Manufacturing Company, Philadelphia, Pennsylvania

MECHANICAL DRAWING

PART II

In Part I the instructions and the problems worked out have been designed to teach the student the elementary operations of Mechanical Drawing, giving him a knowledge of the instruments, an ability to draw a straight and true line, and to make up simple figures. A fair degree of drawing ability is now assumed and we can pass on to more complicated problems. Wherever we turn for subjects, however, we find a knowledge of geometrical figures and their properties is absolutely essential to a clear understanding of the problems chosen and we will therefore turn to a discussion of these geometrical figures and the problems which involve them.

GEOMETRICAL DEFINITIONS

A *point* is used for marking position; it has neither length, breadth, nor thickness.

LINES

A *line* has length only; it is produced by the motion of a point.

A *straight line* or *right line* is one that has the same direction throughout. It is the shortest distance between two points.

A *curved line* is one that is constantly changing in direction. It is sometimes called a curve.

A *broken line* is one made up of several straight lines.

Parallel lines are lines which lie in the same plane and are equally distant from each other at all points.

A *horizontal line* is one having the direction of a line drawn upon the surface of water that is at rest. It is a line parallel to the horizon.

A *vertical line* is one that lies in the direction of a thread suspended from its upper end and having a weight at the lower end. It is a line that is perpendicular to a horizontal plane.

An *oblique line* is one that is neither vertical nor horizontal.

In Mechanical Drawing, lines drawn along the edge of the T-square, when the head of the T-square is resting against the left-hand edge of the board, are called *horizontal* lines. Those drawn at right angles or perpendicular to the edge of the T-square are called *vertical* lines.

If two lines cut each other, they are called *intersecting lines*, and the point at which they cross is called the *point of intersection*.

ANGLES

An *angle* is the measure of the difference in direction of two lines. The lines are called *sides*, and the point of meeting, the

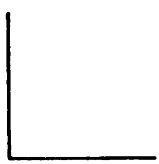


Fig. 40. Right Angle

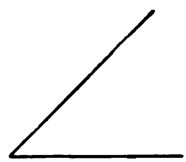


Fig. 41. Acute Angle

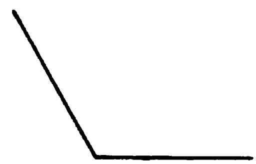


Fig. 42. Obtuse Angle

vertex. The size of an angle is independent of the length of the lines.

If one straight line meets another (extended if necessary), Fig. 40, so that the two angles thus formed are equal, the lines are said to be *perpendicular* to each other and the angles formed are called *right angles*.

An *acute angle* is less than a right angle, Fig. 41.

An *obtuse angle* is greater than a right angle, Fig. 42.

SURFACES

A *surface* is produced by the motion of a line; it has two dimensions—length and breadth.

A *plane figure* is a plane bounded on all sides by lines; the space included within these lines (if they are straight lines) is called a *polygon* or a *rectilinear figure*.

POLYGONS

A *polygon* is a plane figure bounded by straight lines. The boundary lines are called the *sides* and the sum of the sides is called the *perimeter*.

Polygons are classified according to the number of sides.

A *triangle* is a polygon of *three* sides.

A *quadrilateral* is a polygon of *four* sides.

A *pentagon* is a polygon of *five* sides, Fig. 43.

A *hexagon* is a polygon of *six* sides, Fig. 44.

A *heptagon* is a polygon of *seven* sides.

An *octagon* is a polygon of *eight* sides, Fig. 45.

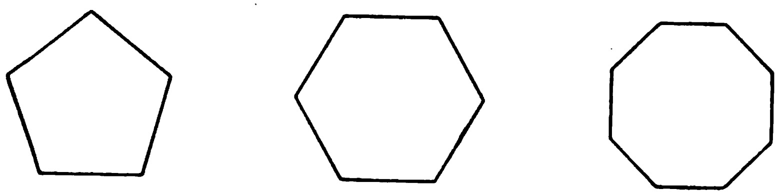


Fig. 43. Pentagon Fig. 44. Hexagon Fig. 45. Octagon

A *decagon* is a polygon of *ten* sides.

A *dodecagon* is a polygon of *twelve* sides.

An *equilateral* polygon is one all of whose sides are equal.

An *equiangular* polygon is one all of whose angles are equal.

A *regular* polygon is one all of whose angles and all of whose sides are equal.

Triangles. A triangle is a polygon enclosed by three straight lines called *sides*. The *angles* of a triangle are the angles formed by the sides.

A *right-angled* triangle, often called a *right* triangle, Fig. 46, is one that has a right angle. The longest side (the one opposite

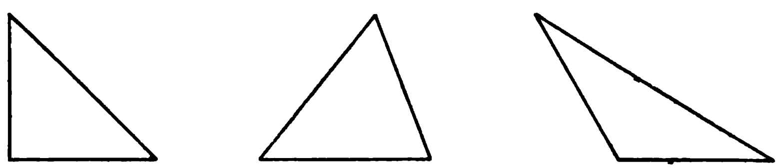


Fig. 46. Right-Angled Triangle Fig. 47. Acute Angled Triangle Fig. 48. Obtuse-Angled Triangle

the right angle) is called the *hypotenuse*, and the other sides are sometimes called *legs*.

An *acute-angled* triangle is one that has all of its angles acute, Fig. 47.

An *obtuse-angled* triangle is one that has an obtuse angle, Fig. 48.

An *equilateral* triangle is one having all of its sides equal, Fig. 49.

An *equiangular* triangle is one having all of its angles equal.

An *isosceles* triangle, Fig. 50, is one, two of whose sides are equal.
A *scalene* triangle, Fig. 51, is one, no two of whose sides are equal.

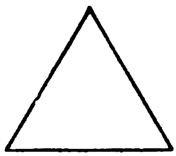


Fig. 49. Equilateral Triangle

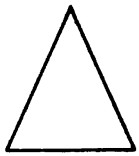


Fig. 50. Isosceles Triangle

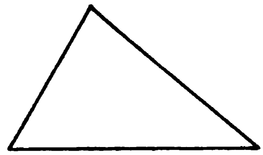


Fig. 51. Scalene Triangle

The base of a triangle is the lowest side; it is the side upon which the triangle is supposed to stand. Any side may, however, be taken as the base. In an isosceles triangle, the side which is not one of the equal sides is usually considered as the base.

The *altitude* of a triangle is the perpendicular drawn from the vertex to the base.

Quadrilaterals. A quadrilateral is a polygon bounded by four straight lines, as Fig. 52.

The *diagonal* of a quadrilateral is a straight line joining two opposite vertices.

Trapezium. A trapezium is a quadrilateral, no two of whose sides are parallel.

Trapezoid. A trapezoid is a quadrilateral having two sides

Fig. 52. Quadrilateral

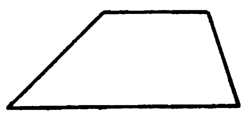


Fig. 53. Trapezoid

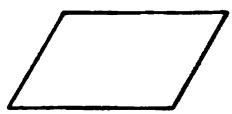


Fig. 54. Parallelogram

parallel, Fig. 53. The parallel sides are called the *bases* and the perpendicular distance between the bases is called the *altitude*.

Parallelogram. A parallelogram is a quadrilateral whose opposite sides are parallel, Fig. 54.

There are four kinds of parallelograms: rectangle, square, rhombus, and rhomboid.

The *rectangle*, Fig. 55, is a parallelogram whose angles are right angles.

The *square*, Fig. 56, is a parallelogram all of whose sides are equal and whose angles are right angles.

The *rhombus*, Fig. 57, is a parallelogram whose sides are equal but whose angles are not right angles.

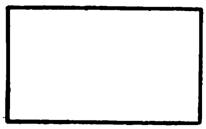


Fig. 55. Rectangle

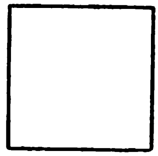


Fig. 56. Square

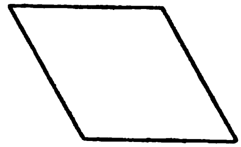


Fig. 57. Rhombus

The *rhomboid* is a parallelogram whose adjacent sides are unequal, and whose angles are not right angles.

CIRCLES

A *circle* is a plane figure bounded by a curved line called the *circumference*, every point of which is equally distant from a point within called the *center*, Fig. 58.

A *diameter* of a circle is a straight line drawn through the center, terminating at both ends in the circumference, Fig. 59.

A *radius* of a circle is a straight line joining the center with the

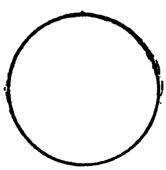


Fig. 58. Circle

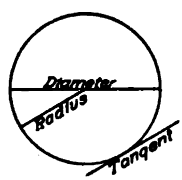


Fig. 59. Diameter and Tangent

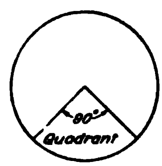


Fig. 60. Quadrant

circumference. All radii of the same circle are equal and their length is always one-half that of the diameter.

An *arc* is any part of the circumference of a circle. An arc equal to one-half the circumference is called a *semi-circumference*, and an arc equal to one-quarter of the circumference is called a *quadrant*, Fig. 60. A quadrant may mean the arc or angle.

A *chord*, Fig. 61, is a straight line which joins the extremities of an arc but does not pass through the center of the circle.

A *secant* is a straight line which intersects the circumference in two points, Fig. 61.

A *segment* of a circle, Fig. 62, is the area included between an arc and a chord.

A *sector* is the area included between an arc and two radii drawn to the extremities of the arc, Fig. 62.

A *tangent* is a straight line which touches the circumference at only one point, called the *point of tangency or contact*, Fig. 59.

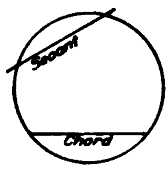


Fig. 61. Chord and Secant

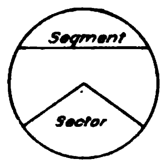


Fig. 62. Segment and Sector

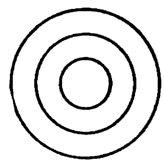


Fig. 63. Concentric Circles

Concentric circles are circles having the same center, Fig. 63.

An *inscribed angle* is an angle whose vertex lies in the circumference and whose sides are chords. It is measured by one-half the intercepted arc, Fig. 64.

A *central angle* is an angle whose vertex is at the center of the circle and whose sides are radii, Fig. 65.

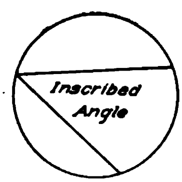


Fig. 64. Inscribed Angle

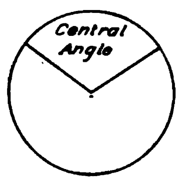


Fig. 65. Central Angle

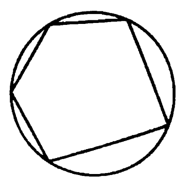


Fig. 66. Inscribed Polygon

An *inscribed polygon* is one whose vertices lie in the circumference and whose sides are chords, Fig. 66.

MEASUREMENT OF ANGLES

To measure an angle, take any convenient radius and describe an arc with the center at the vertex of the angle. The portion of the arc included between the sides of the angle is the *measure of the angle*. If the arc has a constant radius, the greater the divergence of the sides, the longer will be the arc. If there are several arcs drawn with the same center, the intercepted arcs will have different lengths but they will all be the *same fraction* of the entire circumference.

In order that the size of an angle or arc may be stated without saying that it is a certain fraction of a circumference, the circumference is divided into 360 equal parts called *degrees*, Fig. 67. Thus, it may be said that a certain angle contains 45 degrees, *i.e.*, it is $\frac{45}{360}=\frac{1}{8}$ of a circumference. In order to obtain accurate measurements each degree is divided into 60 equal parts called *minutes* and each minute into 60 equal parts called *seconds*.

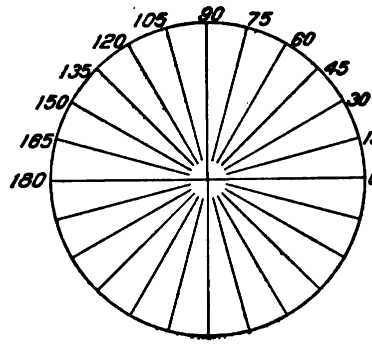


Fig. 67. Angular Measurement

SOLIDS

A *solid* has three dimensions—length, breadth, and thickness. The most common forms of solids are *polyhedrons*, *cylinders*, *cones*, and *spheres*.

POLYHEDRONS

A *polyhedron* is a solid bounded by planes. The bounding planes are called *faces* and their intersections are called *edges*. The intersections of the edges are called *vertices*.

A polyhedron having four faces is called a *tetrahedron;* one having six faces, a *hexahedron;* one having eight faces, and *octahedron*, Fig. 68; one having twelve faces, a *dodecahedron*, etc.

Prisms. A prism is a polyhedron having two opposite faces, called *bases*, which are equal and parallel, and other faces, called

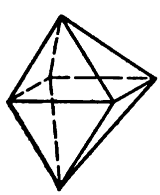


Fig. 68. Octahedron

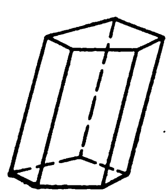


Fig. 69. Prism

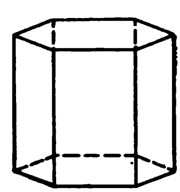


Fig. 70. Right Prism

lateral faces, which are parallelograms, Fig. 69. The *altitude* of a prism is the perpendicular distance between the bases. The area of the lateral faces is called the *lateral area*.

Prisms are called *triangular, rectangular, hexagonal,* etc., according to the shape of the bases. Further classifications are as follows:

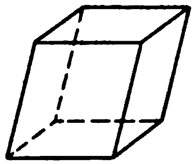


Fig. 71. Parallelopiped

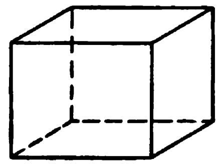


Fig. 72. Rectangular Parallelopiped

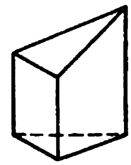


Fig. 73. Truncated Prism

A *right* prism is one whose lateral faces are perpendicular to the bases, Fig. 70.

A *regular* prism is a right prism having regular polygons for bases.

Parallelopiped. A parallelopiped is a prism whose bases are parallelograms, Fig. 71. If all the edges are perpendicular to the bases, it is called a *right parallelopiped.*

A *rectangular parallelopiped* is a right parallelopiped whose bases and lateral faces are rectangles, Fig. 72.

A *cube* is a rectangular parallelopiped all of whose faces are squares.

A *truncated prism* is the portion of a prism included between the base and a plane not parallel to the base, Fig. 73.

Pyramids. A pyramid is a polyhedron whose base is a polygon and whose lateral faces are triangles having a common vertex called the *vertex* of the pyramid.

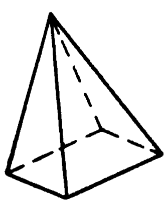


Fig. 74. Pyramid

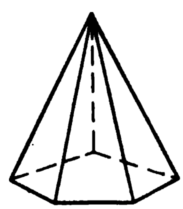


Fig. 75. Regular Pyramid

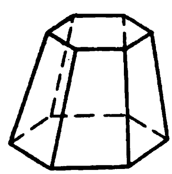


Fig. 76. Frustum of Pyramid

The *altitude* of the pyramid is the perpendicular distance from the vertex to the base.

Pyramids are named according to the kind of polygon forming the base, viz, *triangular, quadriangular,* Fig. 74. *pentagonal,* Fig. 75, *hexagonal.*

A *regular pyramid* is one whose base is a regular polygon and whose vertex lies in a perpendicular erected at the center of the base, Fig. 75.

A *truncated* pyramid is the portion of a pyramid included between the base and a plane not parallel to the base.

A *frustum* of a pyramid is the solid included between the base and a plane parallel to the base, Fig. 76; its *altitude* is the perpendicular distance between the bases.

CYLINDERS

A *cylinder* is a solid having as bases two equal parallel surfaces bounded by curved lines, and as its lateral face the continuous

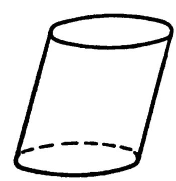


Fig. 77. Cylinder

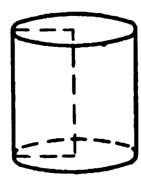


Fig. 78. Right Cylinder

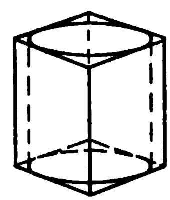


Fig. 79. Inscribed Cylinder

surface generated by a straight line connecting the bases and moving along their circumferences. The bases are usually circles and such a cylinder is called a *circular cylinder,* Fig. 77.

A *right cylinder,* Fig. 78, is one whose side is perpendicular to the bases.

The *altitude* of a cylinder is the perpendicular distance between the bases.

A prism whose base is a regular polygon may be inscribed in or circumscribed about a circular cylinder, Fig. 79.

CONES

A *cone* is a solid bounded by a conical surface and a plane which cuts the conical surface. It may be considered as a pyramid with an infinite number of sides, Fig. 80.

The conical surface is called the *lateral area* and it tapers to a point called the *vertex;* the plane is called the *base.*

The *altitude* of a cone is the perpendicular distance from the vertex to the base.

An *element of a cone* is any straight line from the vertex to the circumference of the base.

A *circular cone* is a cone whose base is a circle.

A *right circular cone,* or *cone of revolution,* Fig. 81, is a cone

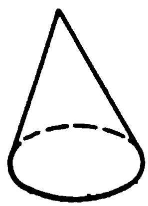


Fig. 80. Cone

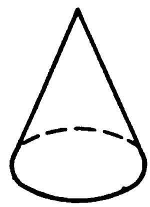


Fig. 81. Right Circular Cone

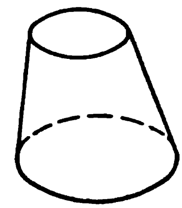


Fig. 82. Frustum of Cone

whose axis is perpendicular to the base. It may be generated by the revolution of a right triangle about one of the legs as an axis.

A *frustum* of a cone, Fig. 82, is the portion of the cone included between the base and a plane parallel to the base; its *altitude* is the perpendicular distance between the bases.

SPHERES

A *sphere* is a solid bounded by a curved surface, every point of which is equally distant from a point within called the *center.*

The *diameter* is a straight line drawn through the center and having its extremities in the curved surface. The *radius*—½ diameter—is the straight line from the eenter to a point on the surface.

A *plane is tangent to a sphere* when it touches the sphere in only

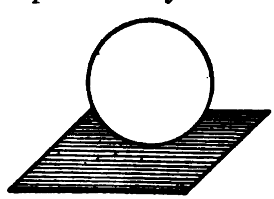


Fig. 83. Plane Tangent to Sphere

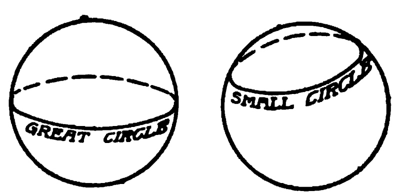


Fig. 84. Great and Small Circle

one point. A plane perpendicular to a radius at its outer extremity is tangent to the sphere, Fig. 83.

An *inscribed polyhedron* is a polyhedron whose vertices lie in the surface of the sphere.

A *circumscribed polyhedron* is a polyhedron whose faces are tangent to a sphere.

A *great circle* is the intersection of the spherical surface and a plane passing through the center of the sphere, Fig. 84.

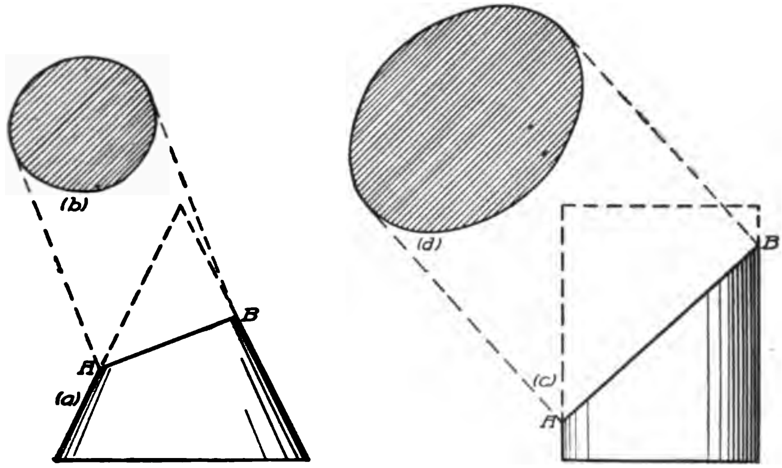


Fig. 85. Intersections of Plane with Cone and Cylinder Giving Ellipses as Shown in (b) and (d)

A *small circle* is the intersection of the spherical surface and a plane which does not pass through the center, Fig. 84.

CONIC SECTIONS

If a plane intersects a cone at various angles with the base the geometrical figures thus formed are called *conic sections*. A plane perpendicular to the base passing through the vertex of a right circular cone forms an isosceles triangle. If the plane is parallel to the base, the intersection of the plane and the conical surfaces will be the circumference of a circle.

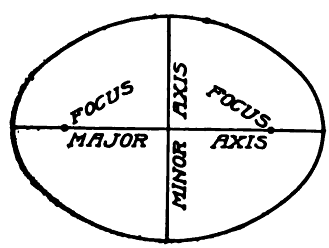


Fig. 86. Diagram Showing Constants of Ellipse

Ellipse. If a plane AB, Fig. 85a, cuts a cone oblique to the axis of the cone, but not cutting the base, the curve formed is called an ellipse, as shown in Fig. 85b, this view being taken perpendicular to the plane AB. If the plane cuts a cylinder as shown in Fig. 85c, the ellipse shown in Fig. 85d is the result, this view being also taken perpendicular to the plane AB. An ellipse may be defined as *a curve generated by a point*

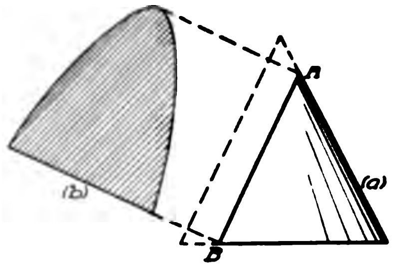


Fig. 87. Intersection of Plane with Cone, Parallel to Element of Cone and Parabolic Section Produced

moving in a plane in such a manner that the sum of the distances from the point to two fixed points shall always be constant.

The two fixed points are called *foci,* Fig. 86, and shall lie on the longest line that can be drawn in the ellipse which is called the *major axis;* the shortest line is called the *minor axis;* and is perpendicular to the major axis at its middle point, called the *center.*

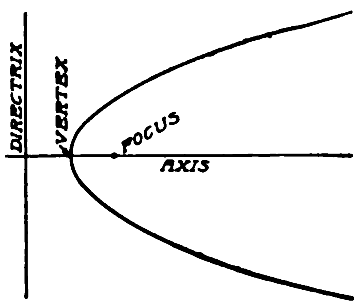


Fig. 88. Diagram Showing Constants of Parabola

An ellipse may be constructed if the major and minor axes are given or if the foci and one axis are known.

Parabola. If a plane AB, Fig. 87a, cuts a cone parallel to an element of the cone, the curve resulting from this intersection is called a parabola, as shown in Fig. 87b, the view being taken perpendicular to the plane AB. This curve is not a closed curve for the branches approach parallelism.

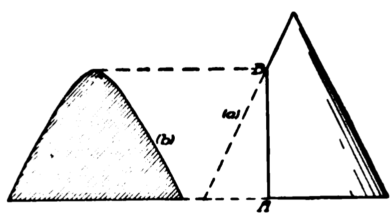


Fig. 89. Intersection of Plane and Cone Parallel with Base and Hyperbolic Section Produced

A parabola may be defined as *a curve every point of which is equally distant from a line and a point.*

The point is called the *focus,* Fig. 88, and the given line, the *directrix.* The line perpendicular to the directrix and passing through the focus is the *axis.* The intersection of the axis and the curve is the *vertex.*

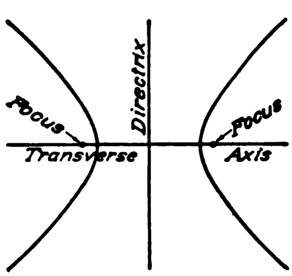


Fig. 90. Diagram Showing Constants of Hyperbola

Hyperbola. If a plane AB, Fig. 89a, cuts a cone parallel to its axis, the resulting curve is called a hyperbola,

Fig. 89b, the view being taken perpendicular to the plane AB.

Like the parabola, the curve is not closed, the branches constantly diverging.

A hyperbola is defined as *a plane curve such that the difference between the distances from any point in the curve to two fixed points is equal to a given distance.*

The two fixed points are the *foci* and the line passing through them is the *transverse axis*, Fig. 90.

Rectangular Hyperbola. The form of hyperbola most used in Mechanical Engineering is called the rectangular hyperbola because it is drawn with reference to rectangular coördinates. This curve is constructed as follows: In Fig. 91, OX and OY are the two coördinate axes drawn at right angles to each other. These lines are also called *asymptotes.* Assume A to be a known point on the curve. Draw AC parallel to OX and AD' perpendicular to OX. Mark off any convenient points on AC such as E, F, G, and H, and through these points draw EE', FF', GG', and HH', perpendicular to OX. Connect E, F, G, H, and C with O. Through the points of intersection of the oblique lines and the vertical line AD' draw the horizontal lines LL', MM', NN', PP', and QQ'. The first point on the curve is the assumed point A, the second point is R, the intersection of LL' and EE', the third the intersection S, and so on.

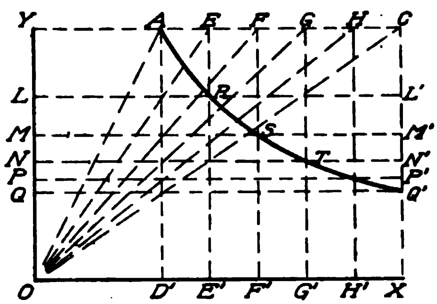


Fig. 91. Construction of Rectangular Hyperbola

In this curve the products of the coördinates of all points are equal. Thus $LR \times RE' = MS \times SF' = NT \times TG'$.

ODONTOIDAL CURVES

Cycloidal Curves. *Cycloid.* The cycloid is a curve generated by a point on the circumference of a circle which rolls on a straight line tangent to the circle, as shown at the left, Fig. 93.

The rolling circle is called the *describing* or *generating circle,* the point on the circle, the *describing* or *generating point,* and the

tangent along which the circle rolls, the *director*. In order that the curve described by the point may be a true cycloid the circle must roll without any slipping.

Hypocycloid. In case the generating circle rolls upon the inside of an arc or circle, the curve thus generated is a hypocycloid,

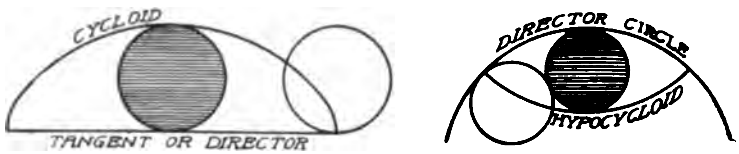


Fig. 92. Geometrical Constructions for Cycloid and Hypocycloid

Fig. 92. If the generating circle has a diameter equal to the radius of the director circle the hypocycloid becomes a straight line.

Epicycloid. If the generating circle rolls upon the *outside* of the *director circle*, the curve generated is an epicycloid, Fig. 93.

Involute Curves. If a thread of fine wire is wound around a cylinder or circle and then unwound, the end will describe an involute curve. The involute may be defined as *a curve generated by a point in a tangent rolling on a circle, known as the base circle*, Fig. 94.

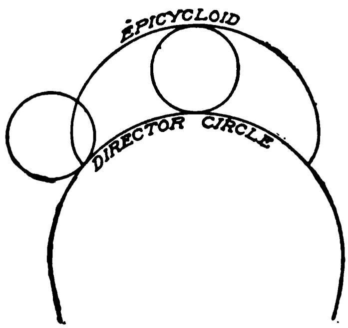


Fig. 93. Geometrical Construction for an Epicycloid

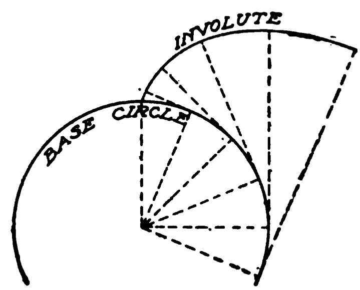


Fig. 94. Geometrical Construction for an Involute

The details of the ellipse, parabola, hyperbola, cycloid, and involute will be taken up in connection with the plates.

The most important application of the cycloidal and involute curves is in the cutting of all forms of gears. It has been found that the teeth of gears when cut accurately to either of these curves will mesh with the least friction and run with exceptional smoothness. The actual application of the cycloidal and involute curves to the laying-out of gears is given in Machine Drawing, Part II.

GEOMETRICAL PROBLEMS

The problems given in Plates IV to VIII inclusive have been chosen because of their particular bearing on the work of the mechanical draftsman. They should be solved with great care, as the principles involved will be used in later work.

PLATE IV

Penciling. The horizontal and vertical center lines and the border lines should be laid out in the same manner as in *Plate I.* Now measure off $2\frac{1}{4}$ inches on both sides of the vertical center line and through these points draw vertical lines as shown by the dot and dash lines, *Plate IV.* In locating the figures, place them a little above the center so that there will be room for the number of the problem.

Draw in lightly the lines of each figure with pencil and after the entire plate is completed, ink them. In penciling, all intersections must be formed with great care as the accuracy of the results depends upon it. Keep the pencil points in good order at all times and draw lines *exactly* through intersections.

Problem 1. *To bisect a given straight line.*

Draw the horizontal straight line $A\,C$ about 3 inches long. With the extremity A as a center and any convenient radius—about 2 inches—describe arcs above and below the line $A\,C$. With the other extremity C as a center and with the same radius draw similar arcs intersecting the first arcs at D and E. The radius of these arcs must be greater than one-half the length of the line in order that they may intersect. Now draw the straight line $D\,E$ passing through the intersections D and E. This line will cut $A\,C$ at its middle point F.
Therefore

$$A\,F = F\,C$$

Proof. Since the points D and E are equally distant from A and C a straight line drawn through them is perpendicular to $A\,C$ at its middle point F.

Problem 2. *To construct an angle equal to a given angle.*

Draw the line $O\,C$ about 2 inches long and the line $O\,A$ of about the same length. The angle formed by these lines may be

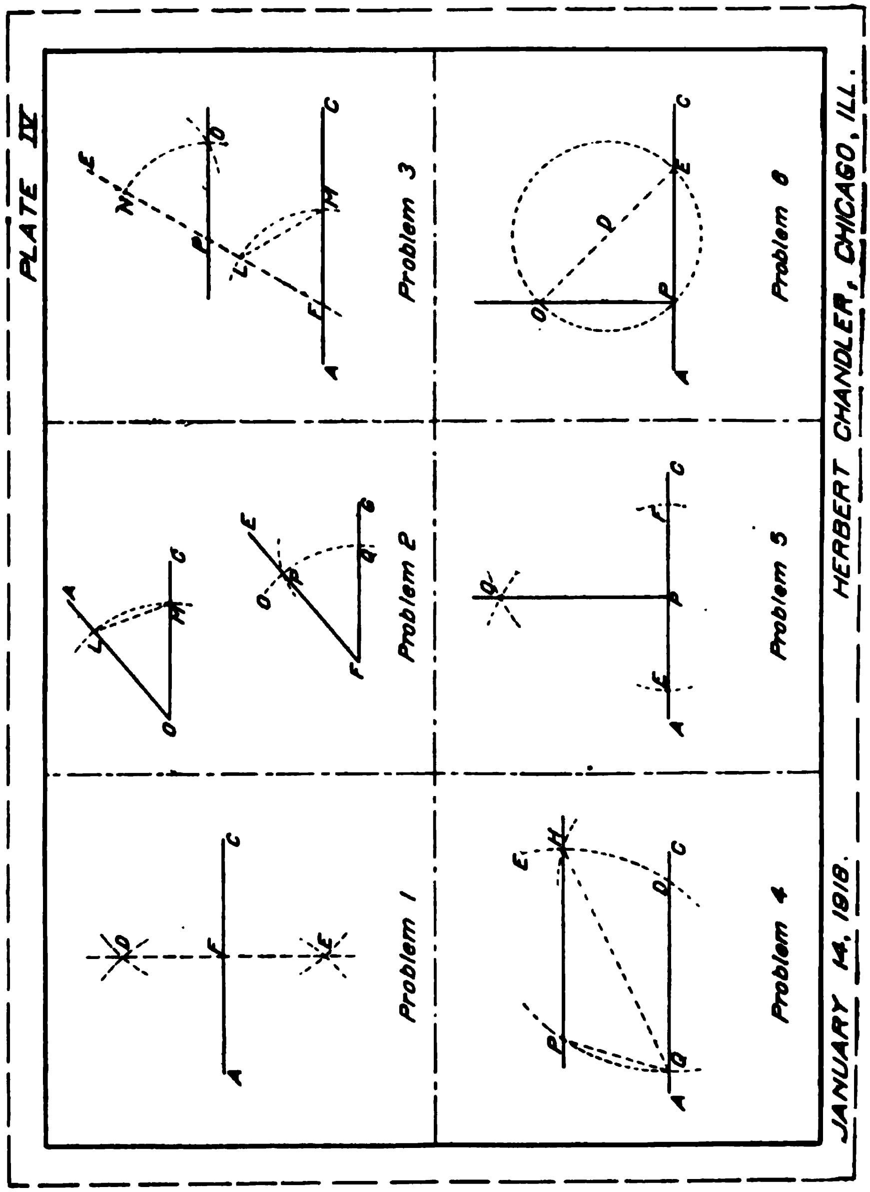


PLATE IV
Problem 1
Problem 2
Problem 3
Problem 4
Problem 5
Problem 6
HERBERT CHANDLER, CHICAGO, ILL.
JANUARY 14, 1918.

any convenient size—about 45 degrees is suitable. This angle $A\ O\ C$ is the given angle.

Now draw $F\,G$, a horizontal line about $2\frac{1}{4}$ inches long, and let F, the left-hand extremity, be the vertex of the angle to be constructed

With O as a center and any convenient radius—about $1\frac{1}{2}$ inches—describe the arc $L\,M$ cutting both $O\,A$ and $O\,C$. With F as a center and the same radius draw the indefinite arc $O\,Q$. Now set the compass so that the distance between the pencil and the needle point is equal to the chord $L\,M$. With Q as a center and a radius equal to $L\,M$ draw an arc cutting the arc $O\,Q$ at P. Through F and P draw the straight line $F\,E$. The angle $E\,F\,G$ is the required angle since it is equal to $A\ O\ C$.

Proof. Since the chords of the arcs $L\,M$ and $P\ Q$ are equal, the arcs are equal. The angles are equal because with equal radii equal arcs are intercepted by equal angles.

Problems 3 and 4. *To draw through a given point a line parallel to a given line.*

First Method. Draw the straight line $A\ C$ about $3\frac{1}{2}$ inches long and assume the point P about $1\frac{1}{2}$ inches above $A\ C$. Through the point P draw an oblique line $F\,E$ forming any convenient angle—about 60 degrees—with $A\ C$. Now construct an angle equal to $P\ F\ C$ having its vertex at P and the line $E\,P$ as one side (See Problem 2.) The straight line $P\ O$ forming the other side of the angle $E\,P\ O$ will be parallel to $A\ C$.

Proof. If two straight lines are cut by a third making the corresponding angles equal, the lines are parallel.

Second Method. Draw the straight line $A\ C$ about $3\frac{1}{4}$ inches long and assume the point P about $1\frac{1}{2}$ inches above $A\ C$. With P as a center and any convenient radius—about $2\frac{1}{2}$ inches—draw the indefinite arc $E\,D$ cutting the line $A\ C$. Now with the same radius and with D as a center, draw an arc $P\ Q$. Set the compass so that the distance between the needle point and the pencil is equal to the chord $P\ Q$. With D as a center and a radius equal to $P\ Q$, describe an arc cutting the arc $E\,D$ at H. A line drawn through P and H will be parallel to $A\ C$.

Proof. Draw the line $Q\,H$. Since the arcs $P\,Q$ and $H\,D$ are equal and have the same radii, the angles $P\,H\,Q$ and $H\,Q\,D$

are equal. Two lines are parallel if the alternate interior angles are equal.

Problems 5 and 6. *To draw a perpendicular to a line from a point in the line.*

First Method. WHEN THE POINT IS NEAR THE MIDDLE OF THE LINE.

Draw the line $A\ C$ about $3\frac{1}{2}$ inches long and assume the point P near the middle of the line. With P as a center and any convenient radius—about $1\frac{1}{4}$ inches—draw two arcs cutting the line $A\ C$ at E and F. Now with E and F as centers and any convenient radius—about $2\frac{1}{2}$ inches—describe arcs intersecting at O. The line $O\ P$ will be perpendicular to $A\ C$ at P.

Proof. The points P and O are both equally distant from E and F. Hence a line drawn through them is perpendicular to $E\ F$ at P.

Second Method. WHEN THE POINT IS NEAR THE END OF THE LINE.

Draw the line $A\ C$ about $3\frac{1}{2}$ inches long. Assume the given point P to be about $\frac{3}{4}$ inch from the end A. With any point D as a center and a radius equal to $D\ P$, describe an arc cutting $A\ C$ at E. Through E and D draw the diameter $E\ O$. A line from O to P is perpendicular to $A\ C$ at P.

Proof. The angle $O\ P\ E$ is inscribed in a semicircle; hence it is a right angle, and the sides $O\ P$ and $P\ E$ are perpendicular to each other.

Lettering. After completing these figures draw pencil lines for the lettering. Place the words "*Plate IV*" and the date and the name in the border, as in preceding plates. To letter the words "Problem 1," "Problem 2," etc., draw three horizontal lines $\frac{1}{4}$ inch, $\frac{3}{8}$ inch, and $\frac{7}{16}$ inch, respectively, above the horizontal center line and the lower border line to serve as a guide for the size of the letters.

Inking. In inking *Plate IV*, ink in the figures first. Make the line $A\ C$, Problem 1, a full line as it is the given line; make the arcs and the line $D\ E$ dotted as they are construction lines. Similarly in Problem 2, make the sides of the angles full lines and the chord $L\ M$ and the arcs dotted. Follow the same plan in inking the lines of Problems 3, 4, 5, and 6. In Problem 6, ink in only that part of the circumference which passes through the points O, P, and E.

After inking the figures, ink in the heavy border line, and the lettering.

PLATE V

Penciling. In laying out the border lines and center lines follow the directions given for *Plate IV*. Draw the dot and dash lines in the same manner, as there are to be six problems on this plate.

Problem 7. *To draw a perpendicular to a line from a point without the line.*

Draw the straight line $A\ C$ about $3\frac{1}{4}$ inches long, and assume the point P about $1\frac{1}{2}$ inches above the line. With P as a center and any convenient radius—about 2 inches—describe an arc cutting $A\ C$ at E and F. The radius of this arc must always be such that it will cut $A\ C$ in two points; the nearer the points E and F are to A and C, the greater will be the accuracy of the work.

Now with E and F as centers and any convenient radius—about $2\frac{1}{4}$ inches—draw the arcs intersecting below $A\ C$ at T. A line through the points P and T will be perpendicular to $A\ C$. In case there is not room below $A\ C$ to draw the arcs, they may be drawn intersecting above the line as shown at N. Whenever convenient draw the arcs below $A\ C$ for greater accuracy.

Proof. Since P and T are both equally distant from E and F, the line $P\ T$ is perpendicular to $A\ C$.

Problems 8 and 9. *To bisect a given angle.*

First Method. WHEN THE SIDES INTERSECT.

Draw the lines $O\ C$ and $O\ A$—about 3 inches long—forming any angle of 45 to 60 degrees. With O as a center and any convenient radius—about 2 inches—draw an arc intersecting the sides of the angle at E and F. With E and F as centers and a radius of $1\frac{1}{2}$ or $1\frac{3}{4}$ inches, describe short arcs intersecting at I. A line $O\ D$, drawn through the points O and I, bisects the angle.

In solving this problem the arc $E\ F$ should not be too near the vertex if accuracy is desired.

Proof. The central angles $A\ O\ D$ and $D\ O\ C$ are equal because the arc $E\ F$ is bisected by the line $O\ D$. The point I is equally distant from E and F.

Second Method. WHEN THE LINES DO NOT INTERSECT.

Draw the lines $A\ C$ and $E\ F$ about 4 inches long making an

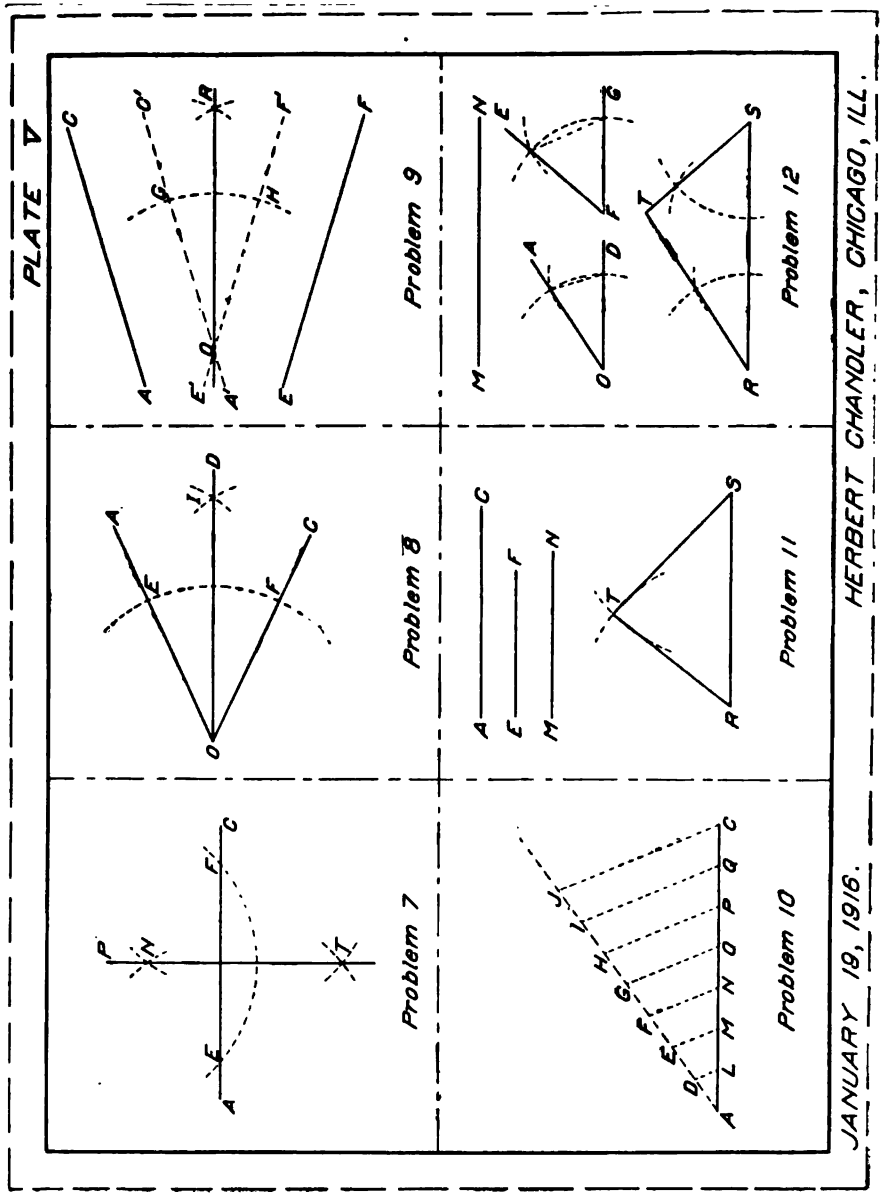


PLATE V
Problem 7
Problem 8
Problem 9
Problem 10
Problem 11
Problem 12
HERBERT CHANDLER, CHICAGO, ILL.
JANUARY 19, 1916.

angle approximately as shown. Draw $A' C'$ and $E' F'$ parallel to $A C$ and $E F$ and at such equal distances from them that they will intersect at O. Now bisect the angle $C' O F'$ by the method given in Problem 8. The line $O R$ bisects the given angle.

Proof. Since $A' C'$ is parallel to $A C$ and $E' F'$ is parallel to $E F$, the angle $C' O F'$ is equal to the angle formed by the lines $A C$ and $E F$. Hence as $O R$ bisects angle $C' O F'$ it also bisects the angle formed by the lines $A C$ and $E F$.

Problem 10. *To divide a line into any number of equal parts.*

Let $A C$—about $3\frac{3}{4}$ inches long—be a given line. Suppose it is desired to divide it into 7 equal parts. First draw the line $A J$ at least 4 inches long, forming any convenient angle with $A C$. On $A J$ lay off, by means of the dividers or scale, points D, E, F, G, etc., each $\frac{1}{2}$ inch apart. (If dividers are used, the spaces need not be exactly $\frac{1}{2}$ inch.) Draw the line $J C$ and through the points D, E, F, G, etc., draw lines parallel to $J C$. These parallels will divide the line $A C$ into 7 equal parts.

Proof. If a series of parallel lines, cutting two straight lines, intercept equal distances on one of these lines, they also intercept equal distances on the other.

Problem 11. *To construct a triangle having given the three sides.*

Draw the three sides, $A C$, $2\frac{3}{4}$ inches long; $E F$, $1\frac{15}{16}$ inches long; and $M N$, $2\frac{3}{16}$ inches long.

Draw $R S$ equal in length to $A C$. With R as a center and a radius equal to $E F$ describe an arc. With S as a center and a radius equal to $M N$ draw an arc cutting the arc previously drawn, at T. Connect T with R and S to form the triangle.

Problem 12. *To construct a triangle having given one side and the two adjacent angles.*

Draw the line $M N$ $3\frac{1}{4}$ inches long and draw two angles $A O D$ and $E F G$ about 30 degrees and 60 degrees respectively.

Draw $R S$ equal in length to $M N$ and with R as a vertex and $R S$ as one side construct an angle equal to $A O D$. In a similar manner construct at S an angle equal to $E F G$. Draw lines from R and S through the two established points until they meet at T. The triangle $R T S$ will be the required triangle.

Lettering. Draw the pencil lines and put in the lettering as in plates already drawn.

Inking. In inking *Plate V*, follow the principles previously used and do not make certain lines dotted until sure that they should be dotted.

After inking the figures, ink in the border lines and the lettering as already explained.

PLATE VI

Penciling. Lay out this plate in the same manner as the preceding plates.

Problem 13. *To describe an arc or circumference through three given points not in the same straight line.*

Locate the three points A, B, and C with a distance between A and B of about 2 inches and a distance between A and C of about $2\frac{1}{4}$ inches. Connect A and B and A and C. Erect perpendiculars to the middle points of $A\ B$ and $A\ C$ as explained in Problem 1. Now draw light pencil lines connecting the intersections I and J and E and F. These lines will intersect at O.

With O as a center and a radius equal to the distance $O\ A$, describe the circumference passing through A, B, and C.

Proof. The point O is equally distant from A, B, and C, since it lies in the perpendiculars to the middle points of $A\ B$ and $A\ C$. Hence the circumference will pass through A, B, and C.

Problem 14. *To inscribe a circle in a given triangle.*

Draw the triangle $L\ M\ N$ of any convenient size. $M\ N$ may be made $3\frac{1}{4}$ inches, $L\ M$, $2\frac{3}{4}$ inches, and $L\ N$, $3\frac{1}{2}$ inches. Bisect the angles $M\ L\ N$ and $L\ M\ N$ by the method used in Problem 8. The bisectors $M\ I$ and $L\ J$ intersect at O, which is the center of the inscribed circle. The radius of the circle is equal to the perpendicular distance from O to one of the sides.

Proof. The point of intersection of the bisectors of the angles of a triangle is equally distant from the sides.

Problem 15. *To inscribe a regular pentagon in a given circle.*

With O as a center and a radius of about $1\frac{1}{2}$ inches, describe the given circle. With the T-square and triangles draw the center lines $A\ C$ and $E\ F$ perpendicular to each other and passing through O. Bisect one of the *radii*, $O\ C$, at H and with this point as a center and a radius $H\ E$, describe the arc $E\ P$. This arc cuts the diameter $A\ C$ at P. With E as a center and a radius $E\ P$, draw arcs cutting

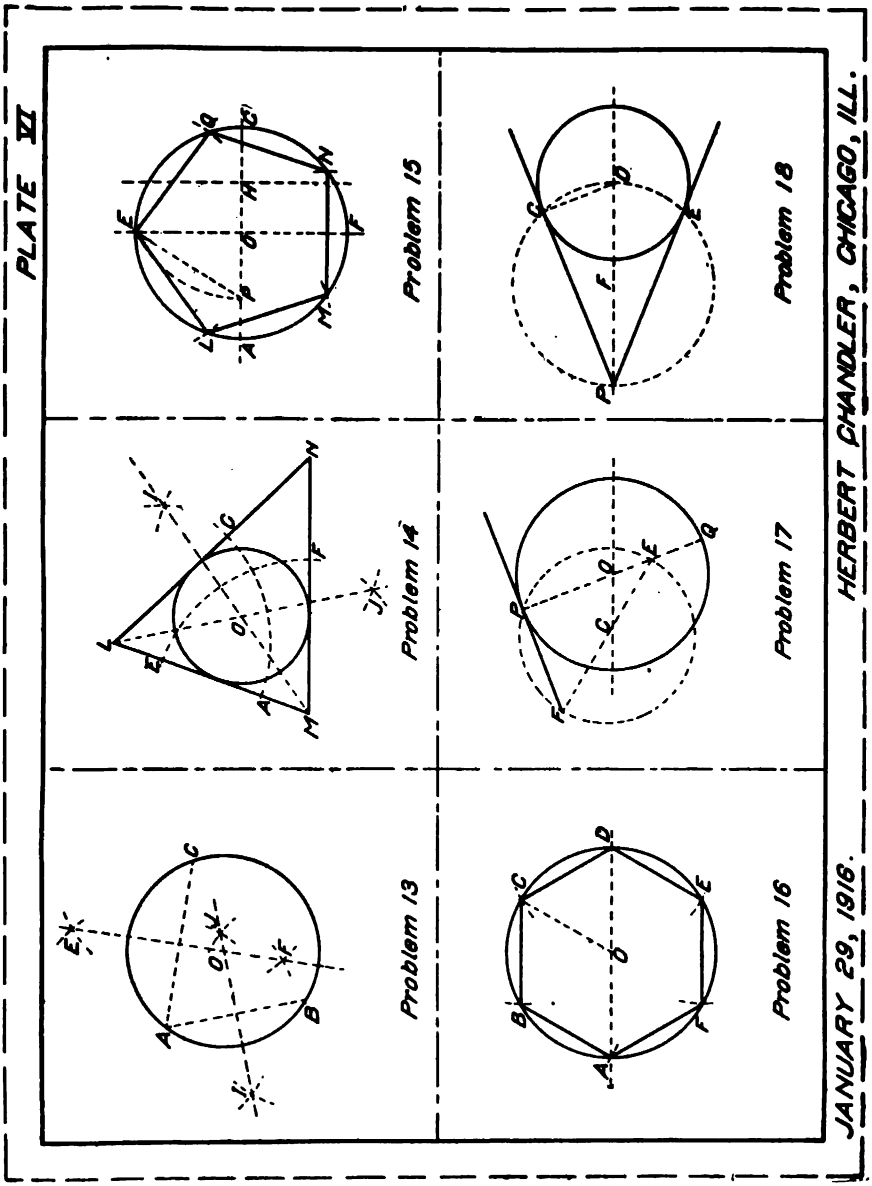


PLATE VI
Problem 13
Problem 14
Problem 15
Problem 16
Problem 17
Problem 18
JANUARY 29, 1916.
HERBERT CHANDLER, CHICAGO, ILL.

the circumference at L and Q. With the same radius and centers at L and Q, draw the arcs cutting the circumference at M and N.

The pentagon is completed by drawing the chords $E\,L$, $L\,M$, $M\,N$, $N\,Q$, and $Q\,E$.

Problem 16. *To inscribe a regular hexagon in a given circle.*

With O as a center and a radius of 1⅜ inches draw the given circle. With the T-square draw the diameter $A\,D$. With D as a center, and a radius equal to $O\,D$, describe arcs cutting the circumference at C and E. Now with C and E as centers and the same radius, draw the arcs, cutting the circumference at B and F. Draw the hexagon by joining the points thus formed.

Therefore, in order to inscribe a regular hexagon in a circle, mark off chords equal in length to the radius.

To inscribe an equilateral triangle in a circle the same method may be used, the triangle being formed by joining the opposite vertices of the hexagon.

Proof. Since the triangle $O\,C\,D$ is an equilateral triangle by construction, the angle $C\,O\,D$ is one-third of two right angles and one-sixth of four right angles. Hence arc $C\,D$ is one-sixth of the circumference and the chord is a side of a regular hexagon.

Problem 17. *To draw a line tangent to a circle at a given point on the circumference.*

With O as a center and a radius of about 1¼ inches draw the given circle. Assume some point P on the circumference and join the point P with the center O. By the method given in Problem 6, *Plate IV*, construct a perpendicular to $P\,O$, which perpendicular will be the desired tangent to the circle at the point P.

Proof. A line perpendicular to a radius at its extremity is tangent to the circle.

Problem 18. *To draw a line tangent to a circle from a point outside the circle.*

With O as a center and a radius of about 1 inch draw the given circle. Assume P some point outside of the circle about 2½ inches from the center. Draw a straight line passing through P and O. Bisect $P\,O$ and with the middle point F as a center describe the circle passing through P and O. Draw a line from P through the intersection of the two circumferences C. The line $P\,C$ is tangent to the given circle. Similarly $P\,E$ is tangent to the circle.

Proof. The angle $P\ C\ O$ is inscribed in a semicircle and hence is a right angle. Since $P\ C\ O$ is a right angle, $P\ C$ is perpendicular to $C\ O$. The perpendicular to a radius at its extremity is tangent to the circumference.

Inking. In inking *Plate VI*, the same method should be followed as in previous plates.

PLATE VII

Penciling. Lay out this plate in the same manner as the preceding plates.

Problems 19 and 20. *To draw an ellipse when the axes are given.*

First Method. Draw the lines $L\ M$ and $C\ D$ about 3¼ and 2¼ inches long respectively, making $C\ D$ perpendicular to $L\ M$ at its middle point P and having $C\ P = P\ D$. The two lines, $L\ M$ and $C\ D$, are the axes. With C as a center and a radius $L\ P$ equal to one-half the major axis, draw the arc, cutting the major axis at E and F. These two points are the foci.

Now locate several points on $P\ M$, such as A, B, and G. With E as a center and a radius equal to $L\ A$, draw arcs above and below $L\ M$. With F as a center and a radius equal to $A\ M$ describe short arcs cutting those already drawn as shown at N. With E as a center and a radius equal to $L\ B$ draw arcs above and below $L\ M$ as before. With F as a center and a radius equal to $B\ M$, draw arcs intersecting those already drawn as shown at O. The point R and others are found by repeating the process. The student is advised to find at least 12 points on the curve—6 above and 6 below $L\ M$. These 12 points with L, C, M, and D will enable him to draw the curve.

After locating these points, draw a free-hand curve passing through them.

Second Method. Draw the two axes $A\ B$ and $P\ Q$ in the same manner as in the first method. With O as a center and a radius equal to one-half the major axis, describe a circle. Similarly with the same center and a radius equal to one-half the minor axis, describe another circle. Draw any radii such as $O\ C$, $O\ D$, $O\ E$, $O\ F$, etc., cutting both circumferences. These radii may be drawn with the 60 and 45 degree triangles. From C, D, E, and F, the points of intersection of the radii with the large circle, draw *vertical* lines and from C', D', E', and F', the points of intersection of the radii with

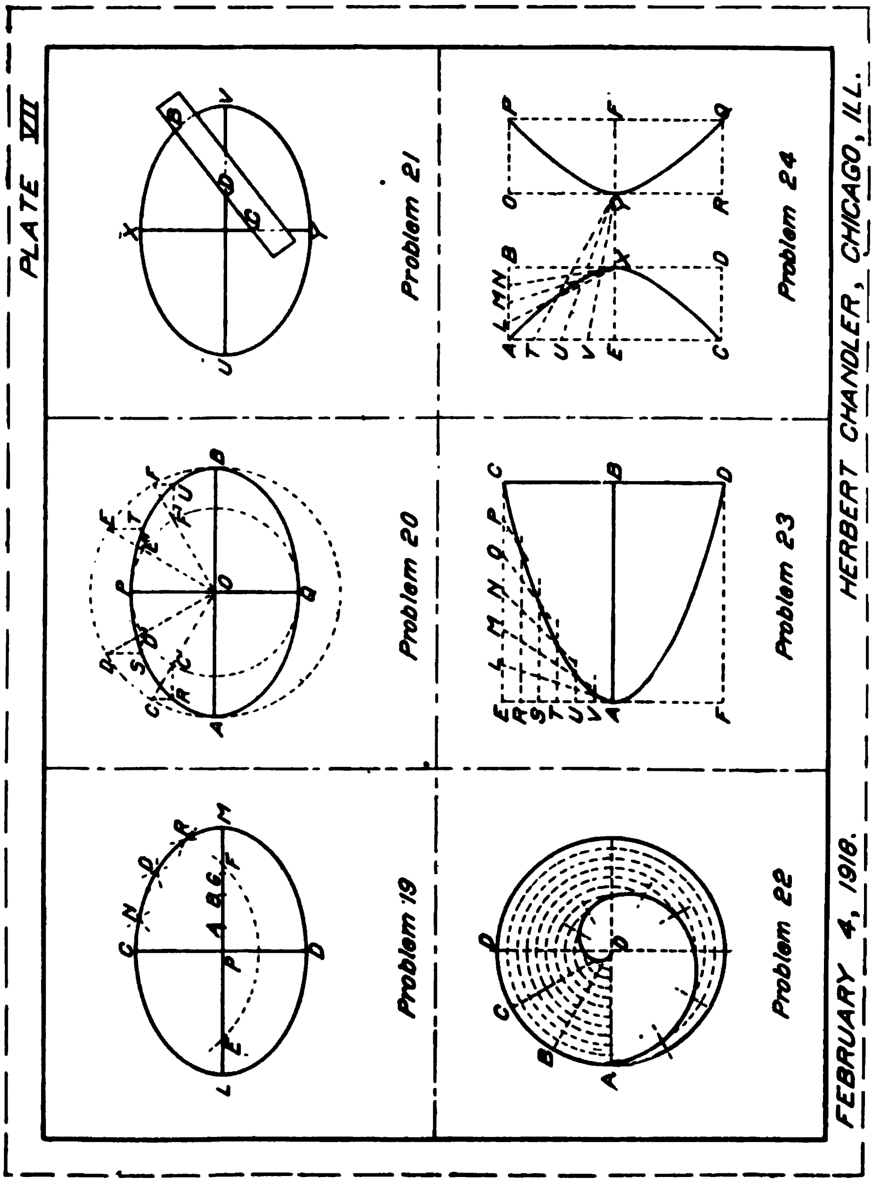


PLATE VII
Problem 19
Problem 20
Problem 21
Problem 22
Problem 23
Problem 24
FEBRUARY 4, 1918.
HERBERT CHANDLER, CHICAGO, ILL.

the small circle, draw *horizontal* lines The intersections of these lines are points on the ellipse.

Draw a free-hand curve* passing through these points; about five points in each quadrant will be sufficient.

Problem 21. *To draw an ellipse by means of a trammel.*

As in Problems 19 and 20, draw the major and minor axes, $U V$ and $X Y$. Take a slip of paper having a straight edge and mark off $C B$ equal to one-half the major axis, and $D B$ equal to one-half the minor axis. Place the slip of paper in various positions keeping the point D on the major axis and the point C on the minor axis. If this is done, the point B will mark various points on the curve. Find as many points as necessary and sketch the ellipse.

Problem 22. *To draw a spiral of one turn in a circle.*

Draw a circle with the center at O and a radius of 1½ inches. Locate twelve points, ⅛ inch apart on the radius $O A$ and draw circles through these points. With the 30-degree triangle, draw radii OB, OC, OD, etc., 30 degrees apart, thus forming 12 equal parts.

The points on the spiral are now located; the first is at the center O; the next is at the intersection of the line $O B$ and the first circle; the third is at the intersection of $O C$ and the second circle; the other points are located in the same way. Sketch in pencil a smooth curve passing through these points.

Problem 23. *To draw a parabola when the abscissa and ordinate are given.*

Draw the straight line $A B$—about three inches long—as the axis, or *abscissa* of the parabola. At A and B draw the lines $E F$ and $C D$ perpendicular to $A B$, and with the T-square draw $E C$ and $F D$, 1½ inches above and below $A B$, respectively. Let A be the vertex of the parabola. Divide $A E$ and $E C$ into the same number of equal parts. Through R, S, T, U, and V, draw horizontal lines and connect L, M, N, O, and P, with A. The intersections of the horizontal lines with the oblique lines are points on the curve. For instance, the intersection of $A L$ and the line V is one point and the intersection of $A M$ and the line U is another.

The lower part of the curve $A D$ is drawn in a similar manner.

Problem 24. *To draw a hyperbola when the abscissa $E X$, the ordinate $A E$, and the diameter $X Y$ are given.*

*See Page 13, Mechanical Drawing, Part I.

Draw $E F$ about 3 inches long and mark the point X, 1 inch from E and the point Y, 1 inch from X. With the triangle and T-square, draw the rectangles $A B D C$ and $O P Q R$ such that $A B$ is 1 inch in length and $A C$, 3 inches in length. Divide $A E$ and $A B$ into the same number of equal parts. Connect Y with the points T, U, and V, on $A E$, and connect X with L, M, and N, on $A B$. The first point on the curve is at A; the next is at the intersection of $T Y$ and $L X$; the third is at the intersection of $U Y$ and $M X$. The remaining points are found in the same manner. Repeat the process for $X C$ and the right-hand curve $P Y Q$.

Inking. In inking the figures on this plate, use the French or irregular curve and make full lines for the curves and their axes. Dot the construction lines as usual. Ink in all the construction lines used in finding one-half of a curve, and in Problems 19, 20, 23, and 24 leave all construction lines in *pencil* except those inked. In Problems 21 and 22 erase all construction lines not inked. The trammel used in Problem 21 may be drawn in the position shown, or outside of the ellipse in any convenient place.

The same lettering should be done on this plate as on previous plates

PLATE VIII

Penciling. In laying out *Plate VIII*, draw the border lines and horizontal and vertical center lines as in previous plates, dividing the plate into four spaces.

Problem 25. *To construct a cycloid when the diameter of the generating circle is given.*

With O' as a center and a radius of $\frac{7}{8}$ inch draw a circle, and, tangent to it, draw the indefinite horizontal straight line $A B$. Divide the circle into any number of equal parts—12 for instance—and through these points of division C, D, E, F, etc., draw horizontal lines. Now with the dividers set so that the distance between the points is equal to the chord of the arc $C D$, mark off the points L, M, N, O, P, on the line $A B$, commencing at the point H. At these points erect perpendiculars to the center line $X O'$ which is the line of centers of the generating circle as it rolls along the line $A B$. With the intersections Q, R, S, T, etc., as centers describe arcs of circles as shown. The points on the cycloid will be the intersections of

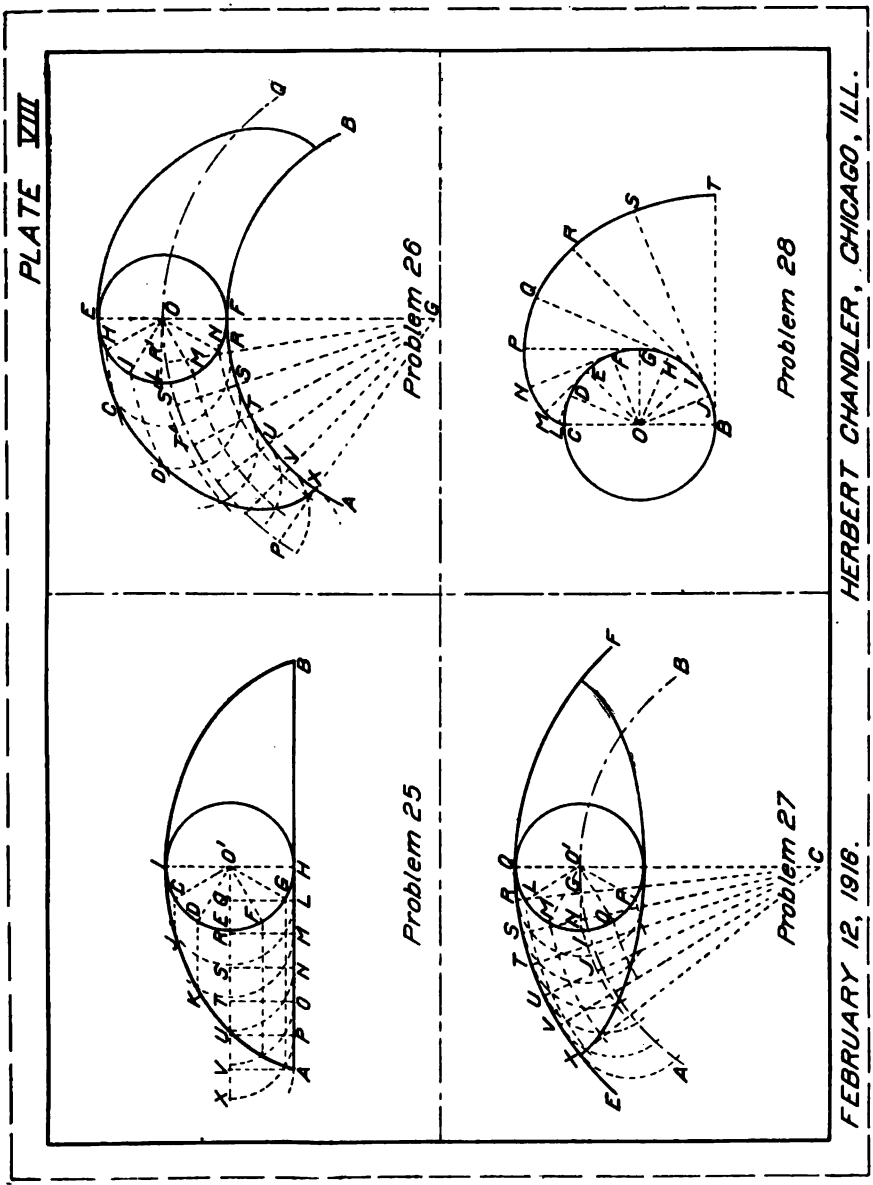


PLATE VIII
Problem 25
Problem 26
Problem 27
Problem 28
FEBRUARY 12, 1916.
HERBERT CHANDLER, CHICAGO, ILL.

these arcs and the horizontal lines drawn through the points *C, D, E, F*, etc. Thus the intersection of the arc whose center is *Q* and the horizontal line through *C* is a point *J* on the curve. Similarly, the intersection of the arc whose center is *R* and the horizontal line through *D* is the point *K* on the curve. The remaining points on the left, as well as those on the right, are found in the same manner. To obtain great accuracy in this curve, the circle should be divided into a large number of equal parts, because the greater the number of divisions the less the error due to the difference in length between a chord and its arc.

Problem 26. *To construct an epicycloid when the diameter of the generating circle and the diameter of the director circle are given.*

The epicycloid and the hypocycloid may be drawn in the same manner as the cycloid if arcs of circles are used in place of the horizontal lines. With *O* as a center and a radius of $\frac{3}{4}$ inch describe a circle. Draw the diameter *E F* of this circle and produce *E F* to *G* such that the line *F G* is $2\frac{3}{4}$ inches long. With *G* as a center and a radius *F G*, describe the arc *A B* of the director circle. With the same center *G*, draw the arc *P Q* which will be the path of the center of the generating circle as it rolls along the arc *A B*. Now divide the generating circle into any number of equal parts—twelve for instance—and through the points of division *H, I, L, M*, and *N*, draw arcs having *G* as a center. With the dividers set so that the distance between the points is equal to the chord *H I*, mark off distances on the director circle *A F B*. Through these points of division *R, S, T, U*, etc., draw radii intersecting the arc *P Q* in the points *R′, S′, T′*, etc., and with these points as centers describe arcs of circles as in Problem 25. The intersections of these arcs with the arcs already drawn through the points *H, I, L, M*, etc., are points on the epicycloid. Thus the intersection of the circle whose center is *R′* with the arc drawn through the point *H* is a point upon the curve. Also the arc whose center is *S′* with the arc drawn through the point *I* is another point on the curve. The remaining points are found by repeating this process.

Problem 27. *To draw an hypocycloid when the diameter of the generating circle and the radius of the director circle are given.*

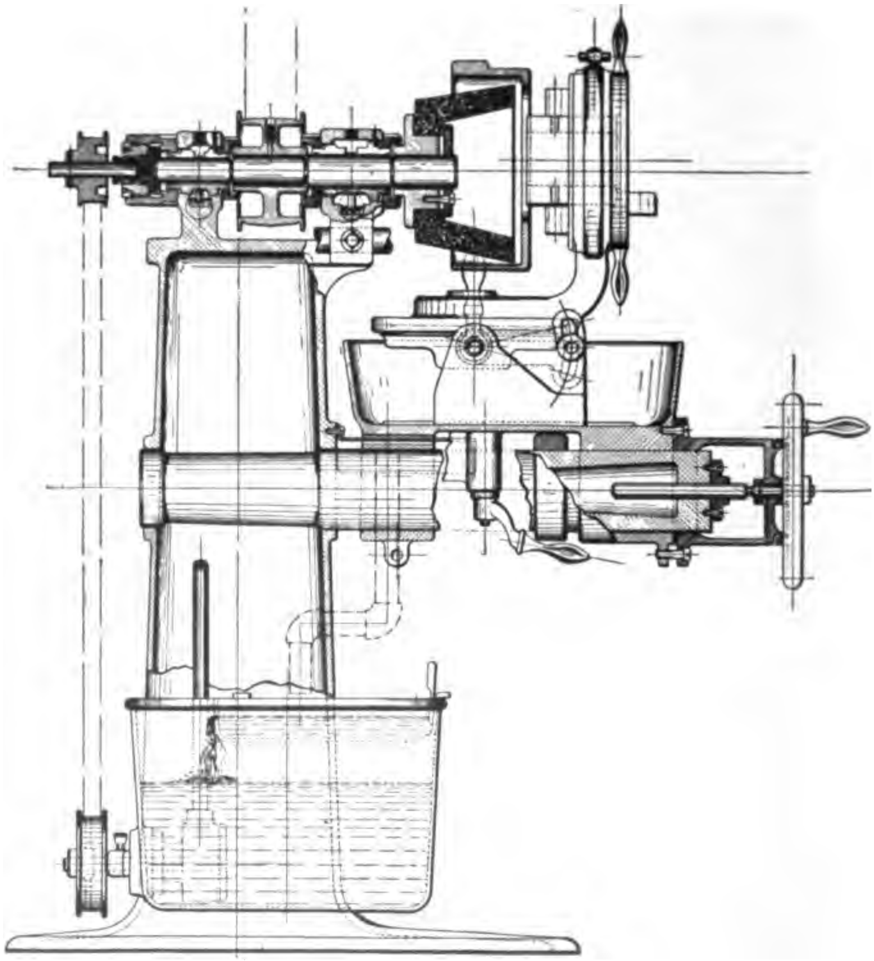
With *C* as a center and a radius of 4 inches describe the arc *E F*, which is the arc of the director circle. Now with the same

center and a radius of 3¼ inches, describe the arc $A\ B$, which is the line of centers of the generating circle as it rolls on the director circle. With O' as a center and a radius of ¾ inch describe the generating circle. As before, divide the generating circle into any number of equal parts—12, for instance—and with these points of division L, M, N, O, etc., draw arcs having C as a center. Upon the arc $E\ F$, lay off distances $Q\ R$, $R\ S$, $S\ T$, etc., equal to the chord $Q\ L$. Draw radii from the points R, S, T, etc., to the center of the director circle C and describe arcs of circles having a radius equal to the radius of the generating circle, using the points G, I, J, etc., as centers. As in Problem 26, the intersections of the arcs are the points on the hypocycloid. By repeating this process, the right-hand portion of the curve may be drawn.

Problem 28. *To draw the involute of a circle when the diameter of the base circle is known.*

With the point O as a center and a radius of 1 inch, describe the base circle. Divide the circle into any number of equal parts—16, for instance—and draw radii to the points of division. At the point D, draw a light pencil line perpendicular to $O\ D$. This line will be tangent to the circle. Similarly at the points E, F, G, H, etc., draw tangents to the circle. Set the dividers so that the distance between the points will be equal to the chord of the arc $C\ D$, and measure this distance from D along the tangent. From the point E, measure on the tangent a distance equal to two of these chords; from the point F, three divisions; and from the point G, four divisions. Similarly, measure distances on the remaining tangents, each time adding the length of the chord. This will give the points L, M, N, P, etc., to T. The curve drawn through these points will be the involute of the circle.

Inking. Observe the same rules in inking *Plate VIII* as were given for *Plate VII*. In Problems 25 and 26 the arcs and lines used in locating the points of the other half of the curve may be left in pencil. In Problem 28, all construction lines should be inked. After completing the problems the same lettering should be done on this plate as on previous plates.



GISHOLT TOOL GRINDER
Courtesy of Gisholt Machine Company, Madison, Wisconsin

MECHANICAL DRAWING

PART III

PROJECTIONS

ORTHOGRAPHIC PROJECTION

Definitions. *Projection.* The word projection means *to throw forward.* In mechanical drawing, the significance is *to throw forward in straight lines.* Projection really means, therefore, either the act or the result of projecting parallel rays from the surface of a body and of cutting these rays with a plane, so as to obtain on the

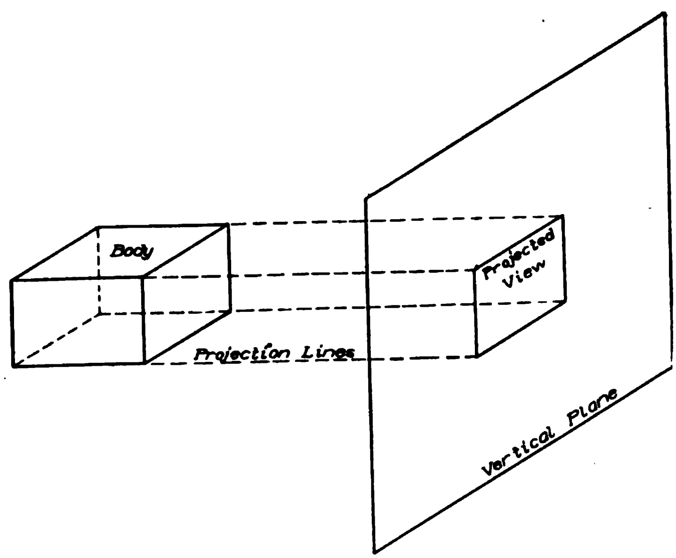


Fig. 95. Body and Its Projection

plane a shape corresponding point for point with that of the body. The rays are called *projecting lines.* A plane may be considered transparent, since it is a flat surface having no thickness.

View. In Fig. 95 a body is shown as projecting from its surface projection lines, and these lines are cut by a plane. By connecting the points on the plane made by the projection lines the

projection of the body is formed, and it corresponds in shape with the body itself. A projection of this kind is called a *view*, this name being given it on account of the fact that an observer on the same side of the body as the projection plane would get this view.

It can readily be seen that one view only will not give a complete picture of a solid object. Usually two or more views are necessary, according to the complication of the object or body. When two or three views are shown, they are pictured on two or three planes at right angles to each other. In this way views of two or three sides are shown, and this is usually sufficient to give the idea of the complete form of the object.

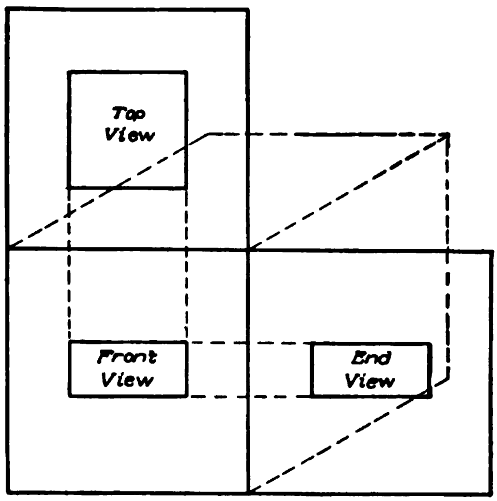


Fig. 96. Projections of Top, Front, and End of Body

Orthographic. The word *orthographic* means at right angles, and in mechanical drawing, in connection with the word projection, it means that two or more views are projected on planes at right angles with each other. The various views of a body have special names—those showing vertical faces are called *elevations*, such as front, side, end or rear elevation; a view of the top of a body is called a *plan* or *plan view;* and a view of the under side, a *bottom view.*

Third-Angle Projection. In Fig. 96 is shown three faces of a body projected on three planes—the top view on the top plane, the front view on the front plane, and the end view on the end plane. It will be seen that the same body is represented as projecting rays in three directions, and thus the three projections, or views, are obtained. It will also be seen that the three planes with their views have been brought into one plane, that is, the surface of the paper. This brings the top view directly above the front view, and the end view to the right of the front view. The above is a definition of

true projection, usually called *third-angle projection,* and is the method used by practically all draftsmen in this country.

First-Angle Projection. There is, however, a method called first-angle projection, used but little now in this country, although formerly in almost general use. Because draftsmen may have to do at times with old drawings or drawings made in foreign countries, it is well for them to understand first-angle projection. This method

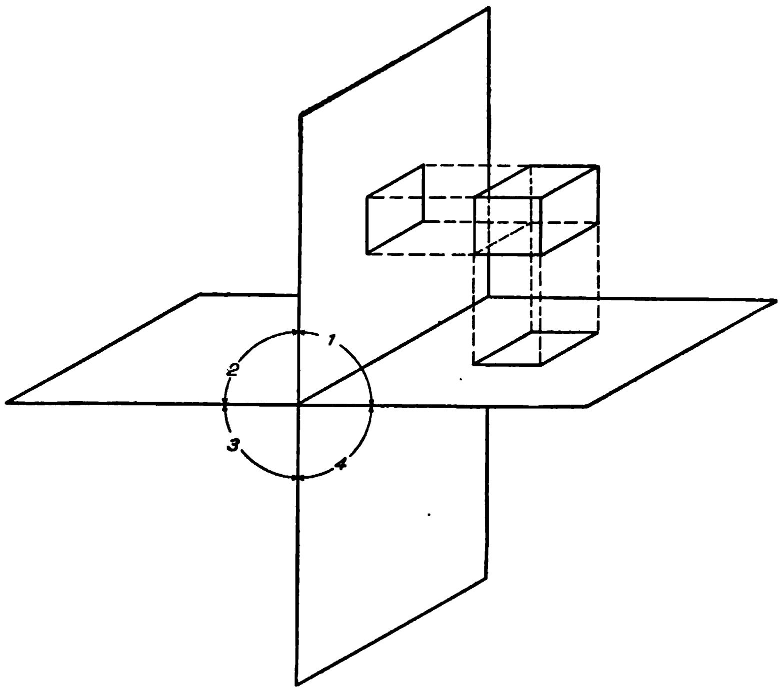


Fig. 97. Body and Its First-Angle Projections

brings the front view, or elevation, above the top view, or plan, the end view being at the right of the front view. Fig. 97 shows this method of first-angle projection.

Comparison of Third- and First-Angle Projection. Perhaps a short explanation will make clear the meaning of first- and third-angle projection. In geometry, when two planes intersect at right angles, the angles are designed as first, second, third, and fourth, as numbered in Fig. 97. In first-angle projection, the body is placed in angle 1, and a top view is projected on a plane under the body.

This passes the projection lines back through the body, instead of throwing them out from the surface. In fact, by this method, the body is supposed to turn itself inside out, an absurdity which led to the general abandonment of the method in this country. Third-angle projection places a body in angle 3, and projects a top view on to the plane above it, and a front view on to the plane in front of it. This is true projection.

Projection Methods. When a drawing is made by projection, an object is represented just as it would be seen if one eye were closed and the other were directly over each point of the object at the same time. As an illustration of this, place a box on a table and a piece of ground glass a few inches in front of it. Now, stand

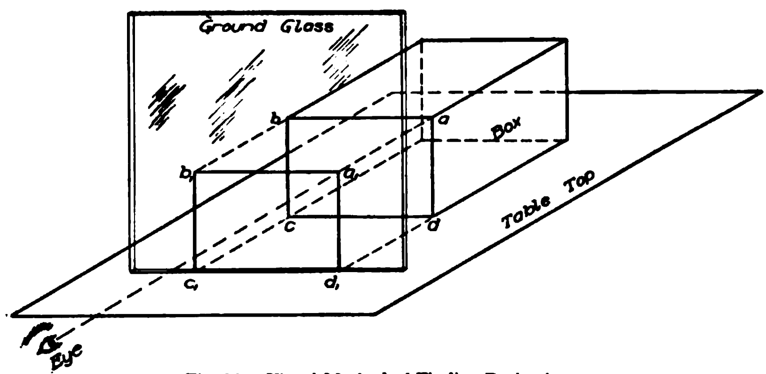


Fig. 98. Visual Method of Finding Projection

so that one eye will come directly in line with one corner a, Fig. 98. Make a dot at a_1 where the line from the eye to the corner a passes through the glass. Next, move the eye until it is directly in line with the corner b of the box, and put a dot at b_1 where the line from the eye to the corner b passes through the glass. Repeat this process, putting dots on the glass at c_1 and d_1 where the lines from the eye to the corners c and d pass through the glass. Now, connect the points a_1, b_1, c_1, and d_1, and the complete projection of the front of the box will be shown by the figure on the glass. This

NOTE. The first four figures in this textbook, Figs. 95, 96, 97, and 98, are pictorial views given to show the student clearly how the views of objects are projected. The student in drawing orthographic projections does not need to draw the pictorial views, but simply the projections, as illustrated in Figs. 99 to 129, inclusive.

figure is a rectangle, and is the same shape and size as the front of the box.

It is readily seen that from this one projection, drawing, or view, no idea of the depth of the box is given, although the width and height are correctly shown. A top, or plan, view must now be made to show the depth of the box. Place another piece of ground glass a few inches above the box and, with the eye directly over each separate corner of the top, repeat the process of making the four dots, representing each top corner. Connect these four dots, and the figure thus formed represents the top projection, or plan view, of the box. Now, arrange the two pieces of glass, as shown in Fig. 99. The box being removed, the upper glass is simply lowered to the table, and the front glass is turned from the bottom forward and up, and laid directly below the upper glass.

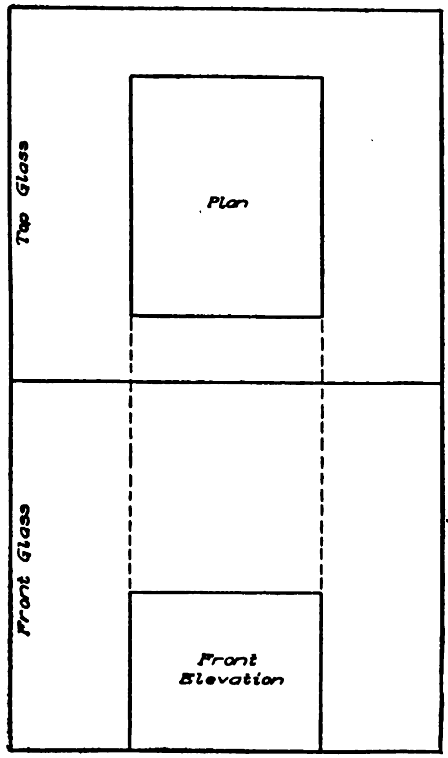


Fig. 99. Plan and Elevation of Box Shown in Fig. 98

This position of the figures represents the two projections—front elevation and plan—just as they would be drawn by a draftsman on a sheet of drawing paper. The width of the box is shown in both views, and being the same in each, the front elevation and plan are both of equal width, and therefore each point in the plan is directly over the corresponding point in the front elevation. In more complicated objects, where the complete idea cannot be obtained from the front elevation and plan views, an end view or both end views must be shown as in Fig. 100, which represents the projections of a box with a curved top. These end views are obtained by taking two or more

pieces of ground glass, placing them one in front of each end, and then drawing the projections. This is done, as in the cases of the

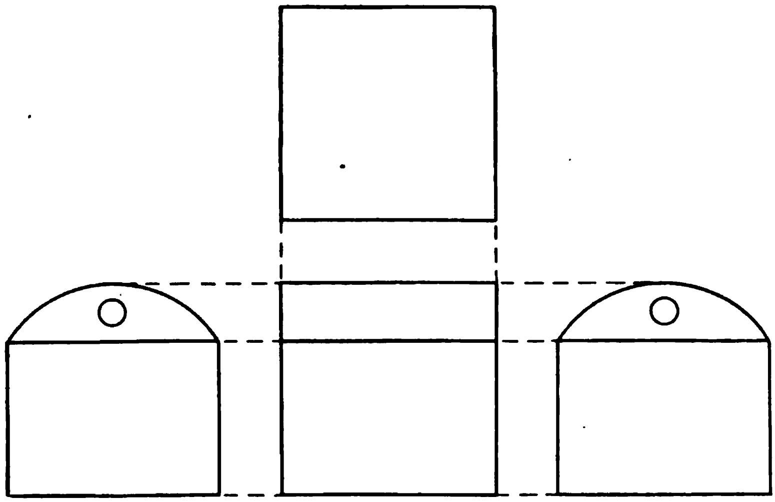


Fig. 100. Plan, Elevation, and End Views of a Box with a Curved Top

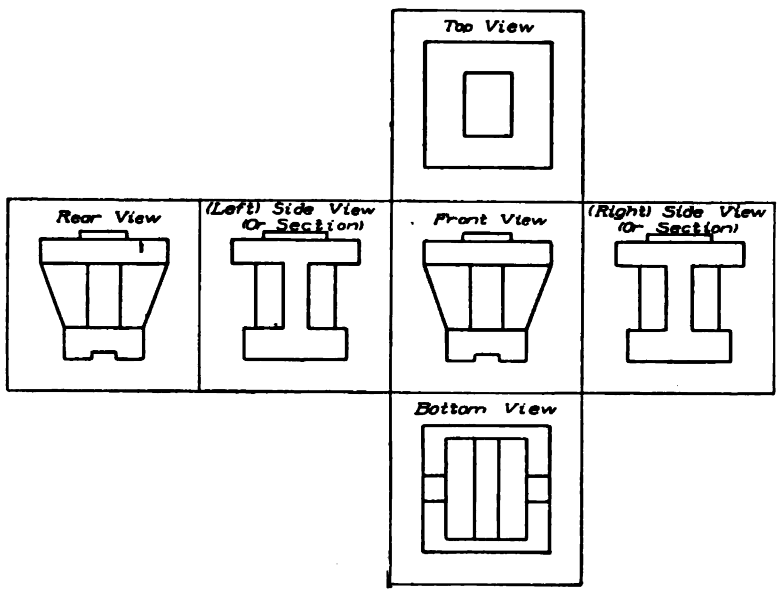


Fig. 101. Six Views of Object
Courtesy of Pennsylvania Railroad Company, Altoona, Pennsylvania

front elevation and plan, by making several dots for the shape of the top, and drawing a curved line through these dots. The two

end views are placed as shown—the right-hand view at the right of the front view, and the left-hand view at the left. This gives the proper arrangement of the view as a draftsman would work them out on paper.

In Fig. 101 is represented a practical case where the object is sufficiently complicated to require a view of each of its six faces. As will be seen in the figure, six views are shown—front, top,

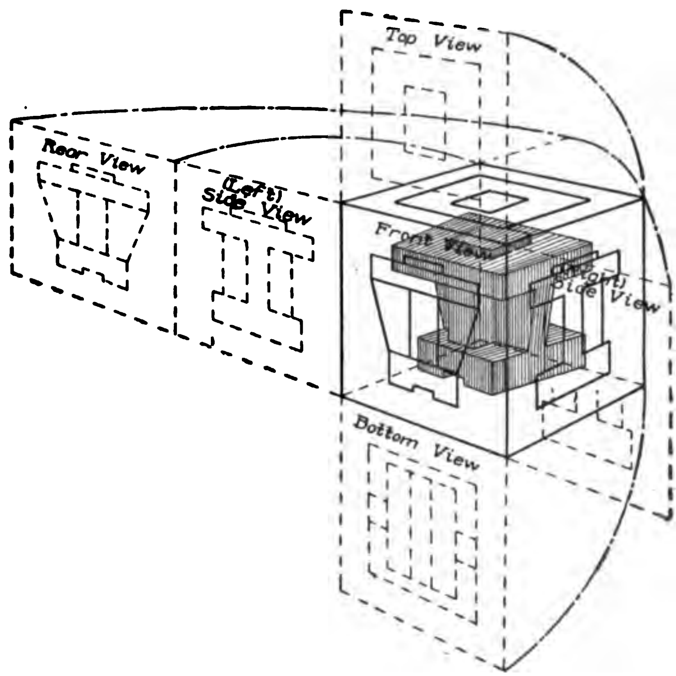


Fig. 102. Folding Out of the Projection Planes Into the Plane of the Surface of the Drawing Paper
Courtesy of Pennsylvania Railroad Company, Altoona, Pennsylvania

bottom, right side, left side, and rear. In Fig. 102 is represented the method of folding out the projection planes after the faces of the object have been projected on them, in order to have them all in one plane—that of the surface of the drawing paper, as shown in Fig. 101.

Drawing the Projection on Paper. From the explanation just given, it will be seen that the projection views are all of the same size as the faces of the object they represent. They can, therefore,

be drawn just as readily on a sheet of drawing paper without the use of the ground glass. For the front view, measure the four front edges of the object, and lay off on the paper a figure of the same shape as the front of the object. Repeat the process for the top of the object, obtaining the top view, or plan; and for each end of the object, obtaining the end view, or side views. The bottom and rear views can be placed in the same way. Draw the plan view with its four corners directly over the four corners of the front view, and the bottom view with its four corners directly under. Draw the right end, or side, view with its four corners directly to the right of the four corners of the front elevation, and the left end, or left side, view and rear view, with their corners directly to the left of the corners of the front view.

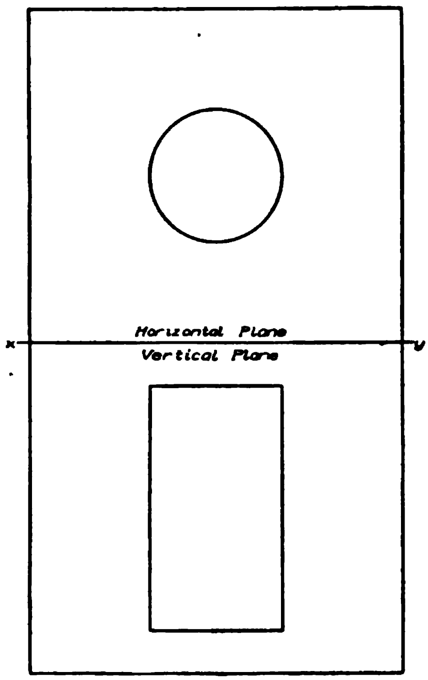


Fig. 163. Ground Line, xy, at Intersection of Horizontal and Vertical Planes

Projection Lines. As each projected point of an object shown in plan view must be directly over the projection of the same point in the front elevation, a vertical dotted line will connect these points, as projected in pairs; and as each projected point in an end view must be directly opposite the projection of the same point in the front elevation, a horizontal dotted line will connect these points, as projected in pairs. These dotted lines are called projections or construction lines.

Ground Line. Having the two planes at right angles on which the front elevation and plan are represented, when the top plane is turned up to bring the plan above the front elevation, as represented on the surface of the drawing paper, it revolves on the intersecting line of the two planes as an axis. This intersecting line xy

in Fig. 103, is called the ground line, and this is usually abbreviated to GL. The projections may be placed at any convenient distance above or below the GL, unless these distances are given in any problem. In beginning all ordinary projection work, it is customary to show the GL as a horizontal line between the front elevation and plan views, and the projection of any pair of points in the front and plan views are always in a line perpendicular to the GL. This is evident from the fact that the points in the plan view are directly

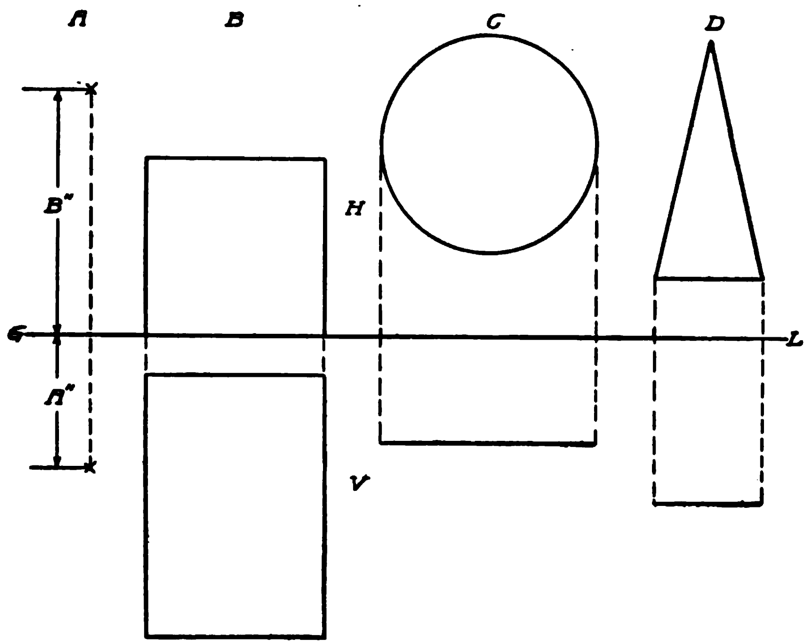


Fig. 104. Typical Projections

over the corresponding points in the front elevation. Although the ground line is usually used in learning the subject of projections, it is customary to omit it in practical work.

Rules of Projection. (1) *If a surface is perpendicular to either plane of projection, its projection on that plane is simply a line—a straight line if the surface is plane, a curved line if the surface is curved.*

(2) *The projected view of any point of any object on a plane is in a perpendicular drawn to the plane through the point of the object.*

(3) *If a straight line is perpendicular to a plane, its projection on that plane is a point; and if the straight line is parallel to the plane, the projection is a line equal in length to the line itself and perpendicular to the ground line.*

(4) *All points on any object at the same height above its base must appear in the front elevation at the same distance below the ground line, and all points on an object at the same distance back of the front face must appear in the plan at the same distance above the ground line.*

Typical Examples of Projection. Figs. 104 and 105 show clearly several ideas of plan and elevation. In such work as this, it is

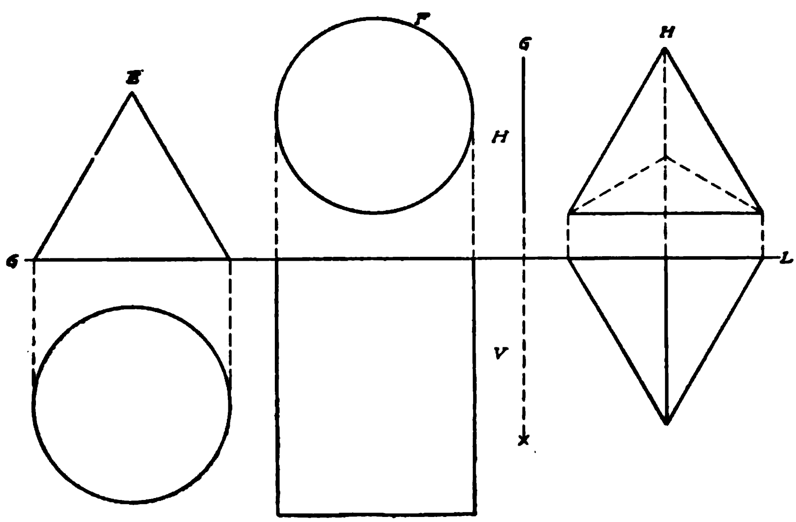


Fig. 105. Typical Projections

customary to call the vertical plane on which the front elevation is drawn V, and the horizontal plane on which the plan is drawn H.

A = a point A'' below H, and B'' in front of V

B = a square prism resting against V, two of its faces parallel to H

C = a circular disk in space parallel to H

D = a triangular card in space parallel to G

E = a cone with its base resting against V

F = a cylinder perpendicular to H, and with one end resting against H

G = a line perpendicular to V

H = a triangular pyramid back of V, with its base resting against H

PRACTICAL PROBLEMS IN PROJECTION

1. *Square Bar.* Fig. 106 represents a square bar. A is the front elevation, and shows the length and width of the bar, but not the thickness. There must then be another view. B is the plan,

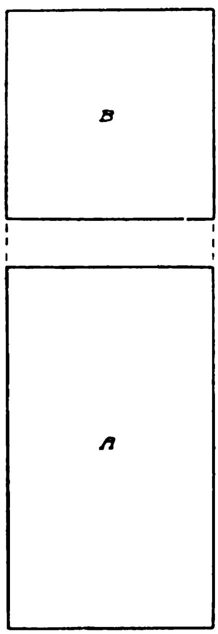


Fig. 106. Projections of Square Bar

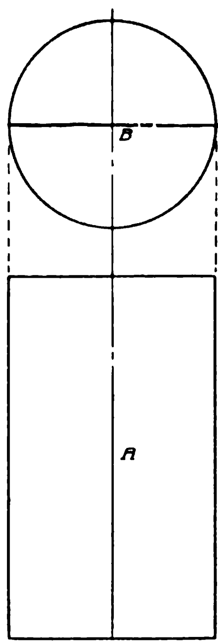


Fig. 107. Projections of Round Bar

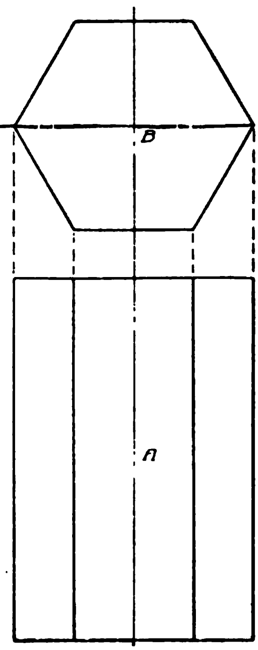


Fig. 108. Projections of Hexagonal Bar

and shows the width and thickness of the bar. From these two views the complete form of the bar is obtained and no other views are necessary when such is the case. In all working drawings, only as many views are shown as is necessary to determine the complete form of the object being drawn.

2. *Round Bar.* Fig. 107 represents a round bar. The front elevation A, shows the width and height of the bar, but does not show that it is round. The plan B, shows the circular top of the bar and of the proper diameter. In this problem, in addition to the

dotted projection lines connecting points in plan and elevation, it is advisable to put in dot and dash lines for center lines. Projection lines and center lines are construction lines, and may be erased when the drawing is finished, unless otherwise ordered.

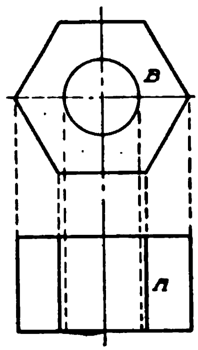


Fig. 109. Projections of Hexagonal Nut

3. *Hexagonal Bar.* Fig. 108 represents a hexagonal bar. In this case, center lines should be drawn. The front elevation *A*, shows the length of the bar, and the plan *B*, shows the form and the distance between faces. The vertical lines in the front elevation show the corners of the hexagonal form while both views show the distance from corner to corner of the hexagonal top.

4. *Hexagonal Nut.* Fig. 109 represents a hexagonal nut. Center lines should be drawn here also. The front elevation *A*, shows the thickness and width of the nut, and the circular hole is shown by heavy dotted lines. Holes are always represented in this way. The plan *B*, shows the shape of the top of the nut, and also the shape of the hole.

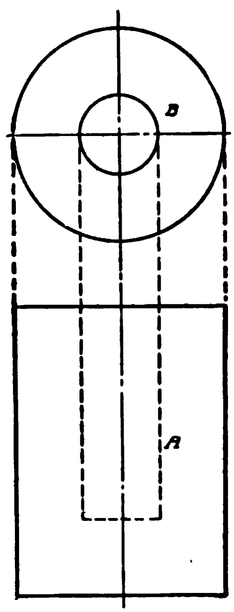


Fig. 110. Projections of Cylinder with Circular Hole

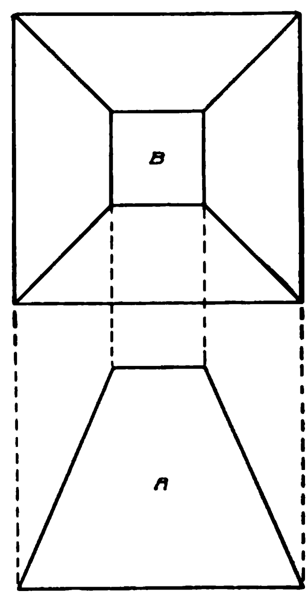


Fig. 111. Projections of Frustum of Square Pyramid

5. *Cylinder with Circular Hole.* Fig. 110 represents a cylinder with a circular hole passing part way through. Center lines are needed here, and in fact where any circle, hexagon, octagon, or other shape except a square or rectangle occurs. The front elevation A, shows the height and width of the cylinder, and the depth and width of hole. The plan B, shows the top of the cylinder, its diameter, and the diameter of the hole.

6. *Frustum of Square Pyramid.* Fig. 111 represents a block in the form of a frustum of a square pyramid. The front elevation A, shows the height of the block, and the width of the top and bottom faces. The plan B, shows the width and depth of the top and bottom faces, and also the edges connecting these faces of the frustum.

7. *Square Bar with Cylindrical Portion.* Fig. 112 represents a square bar with a portion forged to a cylindrical form. The front elevation A, shows the length and width of the bar, and also the length and width of the cylindrical portion. The plan B, shows the square top, and by the dotted circle shows the shape of the cylindrical portion. The fact that this circle is dotted means that the cylindrical portion does not come clear through to the top. A bottom view C, is also shown here, as it gives a better idea of the complete form of the bar. Enough views should always be shown by the draftsman to give the workman a clear idea of what he is to make.

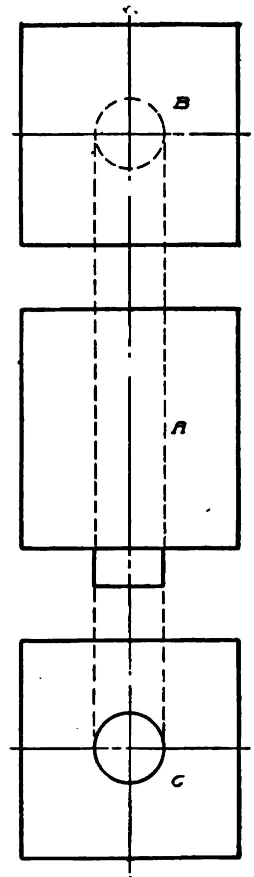


Fig. 112. Projections of Square Bar with Cylindrical Portion

8. *Circular Ring Made from Round Rod.* Fig. 113 represents a circular ring made from a round rod. The front elevation A, shows the thickness and the diameter of the ring, and the plan B, shows the circular form.

9. *Block with Number of Different Dimensions.* Fig. 114 represents a block with a number of different dimensions. The block

has been turned down in such a way that there are five different diameters, as shown. All these diameters, and the lengths between, may be shown in the front elevation A. From this view, only the forms of the cross-section could not be ascertained. Some might be square, some hexagonal, or some circular, but the plan B shows that all are circular.

Summary. The principles of projection which have been used so far, may be stated as follows:

(1) If a line is parallel to either the vertical or horizontal plane, its actual length is shown on that plane, and its other projection is parallel to the ground line.

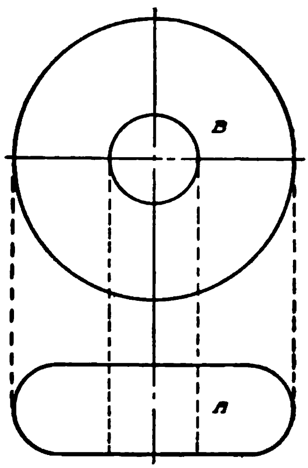


Fig. 113. Projections of Circular Ring

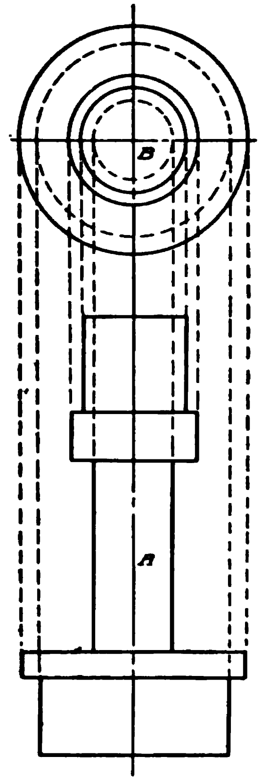


Fig. 114. Projections of Turned Block

(2) A line oblique to either plane has its projections on that plane shorter than the line itself, and its other projection oblique to the ground line.

(3) No projection can be longer than the line itself.

(4) If two lines intersect, their projections must cross, and the point of crossing in the front elevation must be directly under the point of crossing in the plan.

(5) A plane surface, if parallel to either plane, is shown on that plane in its true size and shape; if oblique, it is shown smaller than the true size, and if perpendicular it is shown as a straight line.

(6) Lines parallel in space have both their vertical and horizontal projections parallel.

TRUE LENGTH OF LINES

Principles. If a line is parallel to a plane, its projection on that plane will be equal in length to the line itself, as represented in Fig. 115. If a line is perpendicular to a plane, its projection on the plane will be a point, as represented by the cross in Fig. 116. If a line is inclined to a plane, its projection on that plane will be shorter than the line itself, as represented in Fig. 117. If a line is parallel to the horizontal or vertical plane, its projection on the other plane will be parallel to the ground line, as represented in Fig. 118. A line inclined to both the horizontal and vertical planes will not show its true length in either projection, as represented in Fig. 119. In a case like the one last mentioned, the true length of the line is found by revolving the line until it is parallel to one of the planes. Then, its projection on that plane will be its true length.

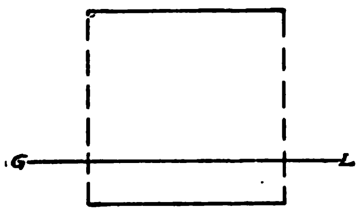


Fig. 115. Projections of a Line Parallel to Plane

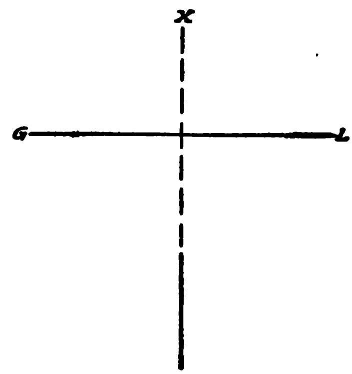


Fig. 116. Projections of a Line Perpendicular to a Plane

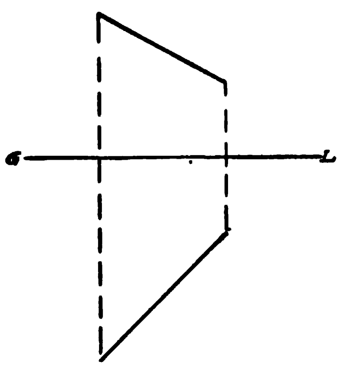


Fig. 117. Projections of a Line Inclined to Plane

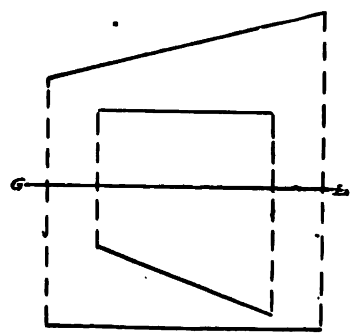


Fig. 118. Projections of Lines Parallel to Ground Line

True Length by Revolving Horizontal Projection. In Fig. 120 is shown the horizontal and vertical projections of the line AB, and to find the true length of the line itself proceed as follows: Swing the horizontal projection A^hB^h about one end A^h as a pivot, until it is parallel to the ground line. Project the new point $B_1{}^h$ downward to a point on the vertical plane to a line drawn from B^v parallel to the ground line, locating the point $B_1{}^v$. The line connecting $B_1{}^v$ and A^v is the true length desired, since the true length of a line is always shown by its projection on a plane when the line is parallel to that plane.

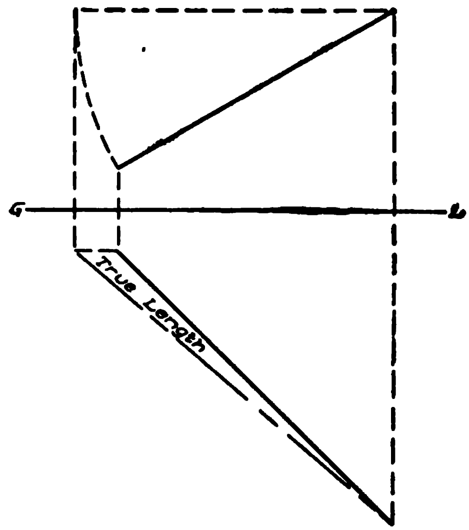


Fig. 119. True Length of Inclined Line not Shown in Its Projections

True Length by Revolving Vertical Projection. In Fig. 121 is shown the method of finding the true length of the same line as

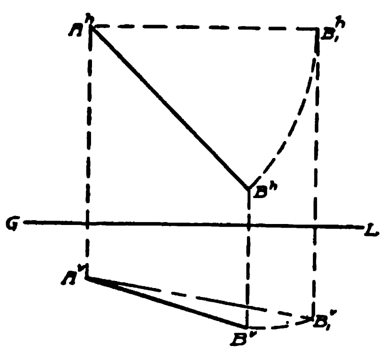


Fig. 120. True Length of a Line by Revolving Horizontal Projection

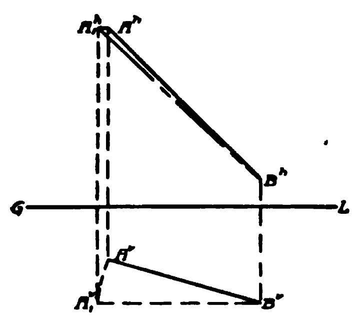


Fig. 121. True Length of a Line by Revolving Vertical Projection

in Fig. 120, but by revolving the vertical projection. The method is the same. Revolve A^vB^v about the end B^v as a pivot until it is parallel to the ground line, and then project $A_1{}^v$ up to $A_1{}^h$ on the

horizontal plane at the same distance from the ground line as A^h. The true length is then shown on the horizontal plane by the line connecting A_1^h and B^h. Projection lines representing the true length are always shown as dot and dash lines, as in Fig. 120 and 121.

REPRESENTATION OF OBJECTS

Rectangular Prism or Block. In Fig. 122 there is represented a rectangular prism or block, whose length is twice its width. The elevation shows its height. As the block is placed at an angle, three of the vertical edges will be visible, and the fourth, invisible. In mechanical drawing, the edges, which in projection form a part of the outline or contour of the figure, must always be visible, hence are always drawn as full lines, while the lines or edges which are invisible are drawn dotted. The plan shows what lines are visible in elevation, and the elevation determines what are visible in plan. In Fig. 122, the plan shows that the dotted edge AB is the back edge, and in Fig. 123, the elevation shows that the dotted edge CD is the lower edge of the triangular prism. In general, if in elevation an edge projected *within* the figure is a back edge, it must be dotted, and in plan, if an edge projected within the outline is a lower edge, it is dotted.

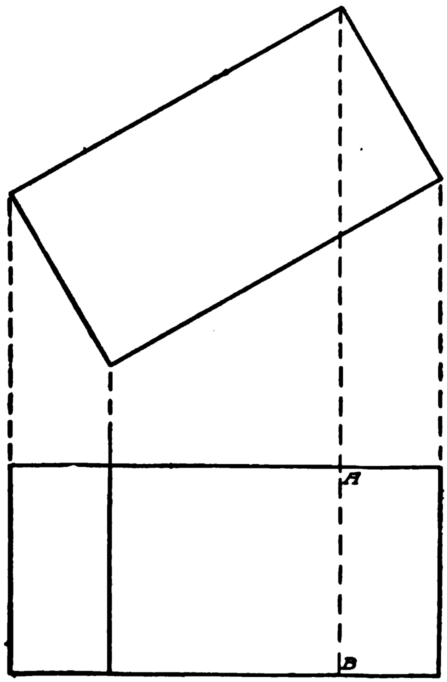


Fig. 122. Projections of a Rectangular Prism or Block

Triangular Prism or Block. The end view shown in Fig. 123 is obtained by projecting the points of the plan across to a plane at right angles to the horizontal and vertical planes, then revolving them down through 90 degrees and continuing the projections to meet the projection lines drawn across from

the elevation. Connecting the points thus obtained gives the end view. End or side views of any object are obtained by projection in this way.

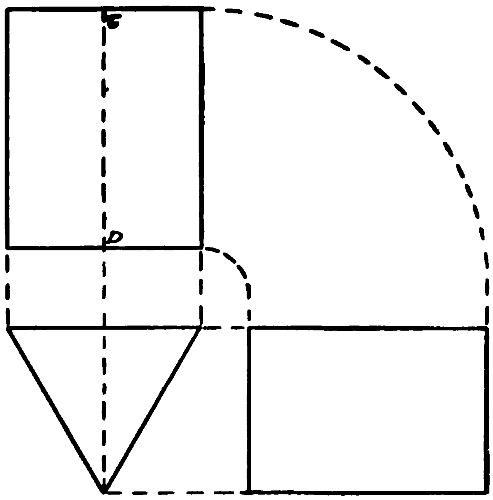


Fig. 123. Projections of a Triangular Prism or Block

Triangular Block with Square Hole. The plan, elevation, and end views of a triangular block with a square hole from end to end are shown in Fig. 124. In this case the plan and elevation alone would not be sufficient to positively determine the shape of the hole, but the end view shows at a glance that it is square.

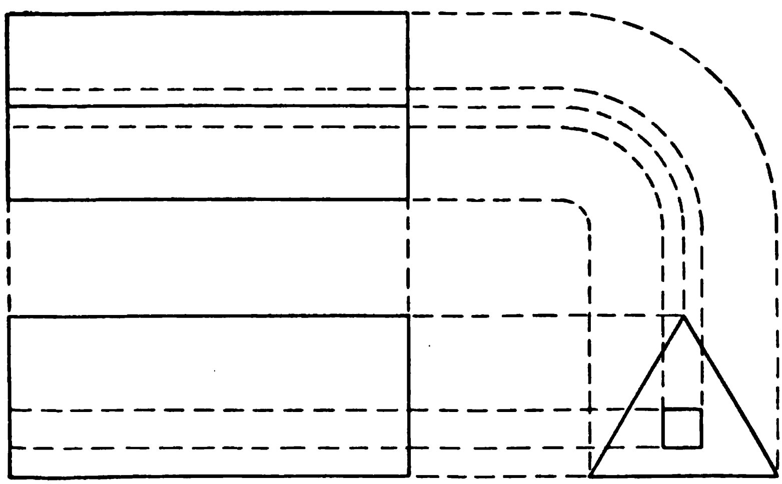


Fig. 124. Projections of a Triangular Block with Square Hole

ROTATING AND INCLINING OF OBJECTS

Method of Rotating Object. The natural way to place an object to be shown by projections would be in the simplest position; that is, with an edge or face parallel to either the horizontal or

vertical plane of projection. Sometimes it is necessary, however, to draw the views of an object in a position at an angle to the planes. In such case it is usually advisable to draw the object parallel to one of the planes, and then rotate it to the required position about an axis perpendicular to a plane of projection.

When an object is rotated in this way, about an axis perpendicular to a plane, its projection on that plane will remain unchanged

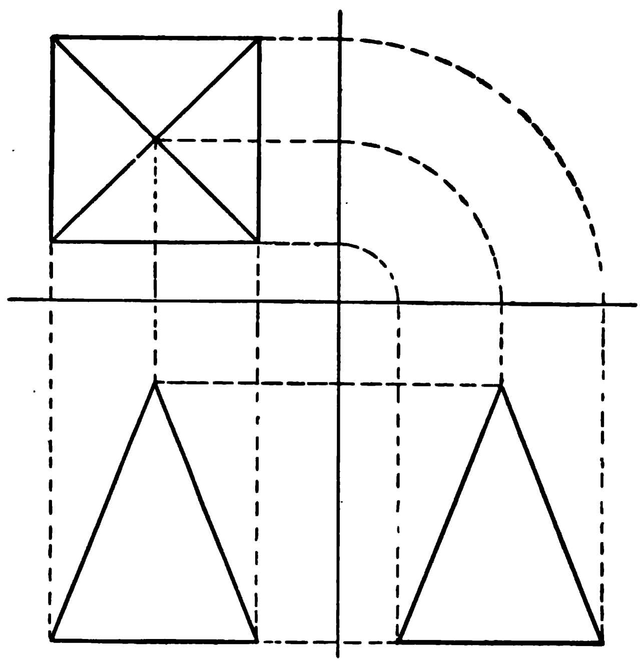


Fig. 125. Plan, Front, and Side Views of a Square Pyramid

in size and shape, and the dimensions parallel to this axis on the other planes will remain the same.

Pyramid. In Fig. 125, the plan, front, and side views of a pyramid are shown, and in Fig. 126 is shown the same pyramid after it has been rotated through 30 degrees about an axis perpendicular to the horizontal plane. The height of the pyramid has not been altered by this rotation and, therefore, the front and side views are the same height as in the original front view.

Now, if the pyramid in Fig. 125 is rotated about an axis perpendicular to the vertical plane, the front view will not be altered,

and may be copied in the new position at an angle of 30 degrees, as shown in Fig. 127. The distance above the ground line to any point in the top view are not altered, and the distances of the various points can be taken on the lines projected up from the points of the front view with a pair of dividers, or the points can be obtained by projecting across from the original top view to meet the projection lines drawn up from the front view. The side view dimensions are not altered, and this view can therefore be obtained in

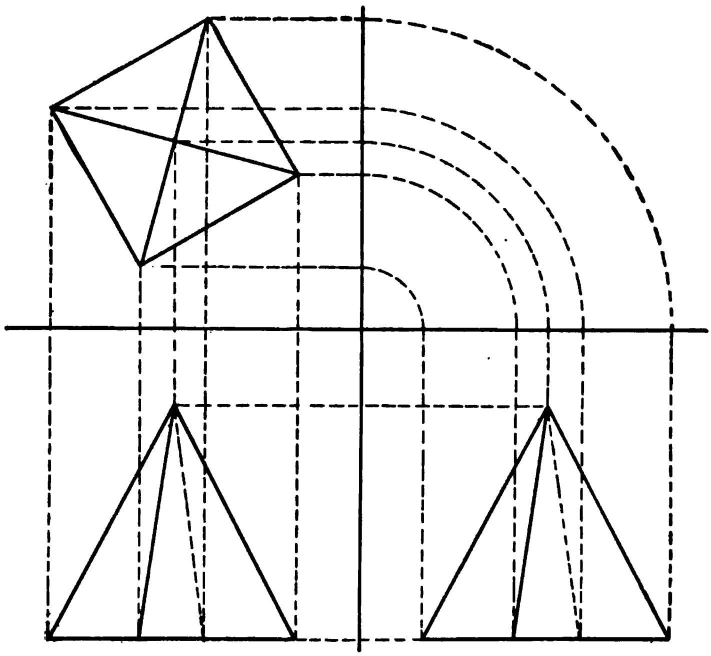


Fig. 126. Plan, Front and Side Views after Revolving Pyramid in Fig. 125 through 30 Degrees with Vertical Plane

the usual way, by projecting across from the front view, and revolving down from the plane at right angles to the horizontal and vertical planes the points projected across from the top view.

Cylinder in Inclined Position to Horizontal Plane. As shown in Fig. 128, first draw the plan, a circle, at *A*. Then draw the rectangle at *B*, representing the front view. Now, draw the rectangle at *C*, representing the front view at the desired angle. This rectangle *C* is the same size as the view at *B*, since the cylinder

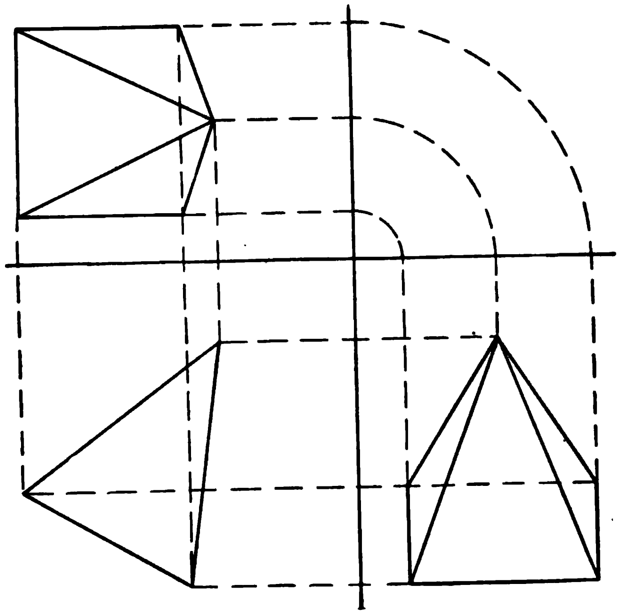


Fig. 127. Plan, Front, and Side Views after Revolving Pyramid in Fig. 125 through 30 Degrees with Horizontal Plane

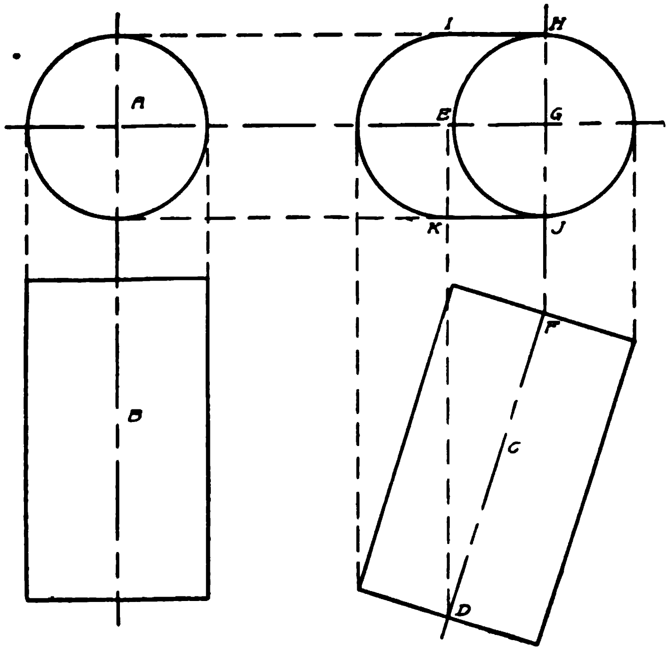


Fig. 128. Projections of Cylinder Inclined to Horizontal Plane

has simply been inclined to the horizontal plane, but kept parallel to the vertical plane. The point *D*, the center of the circle forming the base of the cylinder, is projected up to the point *E*, and with this point as a center, a circle representing the plan view of the base is drawn. Then from *F* project up to *G*, and with this point as a center draw the circle representing the plan view of the top of the

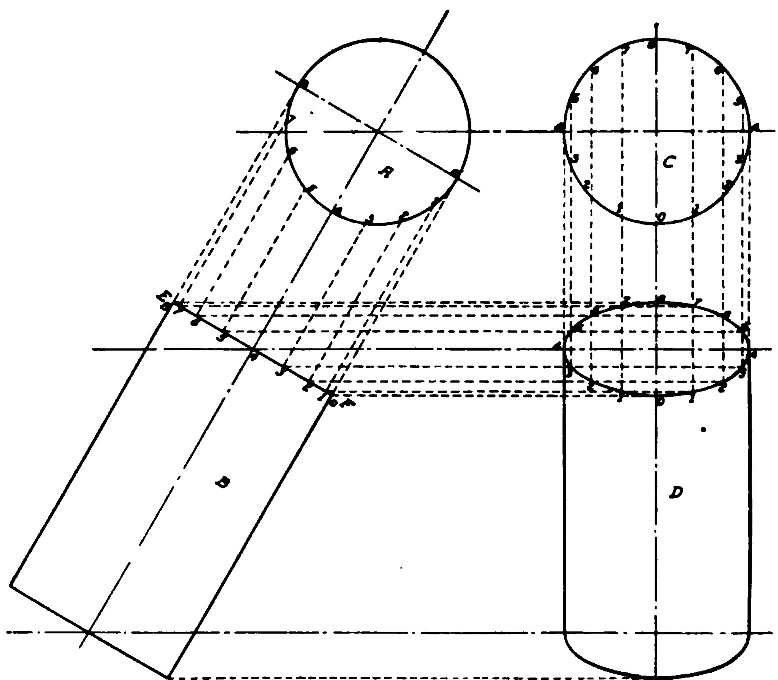


Fig. 129. Method of Finding the Projection, in the Form of an Ellipse, of the Top of a Cylinder Greatly Inclined to a Plane

cylinder. Connecting these two circles with horizontal lines *HI* and *JK*, representing the sides of the cylinder, completes the plan view, and the problem is finished.

As the cylinder is at an angle with the horizontal plane, it will be seen that the top and bottom of the cylinder in the plan view are not circles, but ellipses. It is, however, customary to draw them with the compass, as circles, when the angle of the cylinder with the plane is not great.

Cylinder Greatly Inclined to Horizontal Plane. In Fig. 129 the plan and front elevation of the top of the cylinder are drawn at the desired angle with the horizontal plane at A and B, respectively. The plan view at A is then transferred to C. In each of these plan views divide the lower semicircle into a number of equal parts, eight in this case. From the view of A, project the points 0—8, parallel to the center line, down to EF, and then project across to the projection lines drawn vertically down from the points 0—8 in C. The points of intersection of projection lines, correspondingly numbered, form the shape of the ellipse representing the top of the side view of the inclined cylinder D, and the ellipse drawn through these points completes this view. The side lines of the cylinder may now be drawn, and the curve representing the bottom of the side view may easily be copied from the lower half of the ellipse representing the top view. When the points have been located, the ellipses may be drawn through them with the aid of an irregular curve.

ILLUSTRATIVE EXAMPLES

1. *Construct plan and elevation of a regular hexagonal pyramid.* It is evident that two distinct geometrical views are necessary to convey a complete idea of the form of the object; an elevation to represent the sides of the body, and to express its height; and a plan of the upper surface to express the form horizontally.

It is to be observed that this body has an imaginary axis or center line, about which the same parts or segments of the body are equally distant; this is an essential characteristic of all symmetrical figures.

Draw a horizontal dotted line MN for the center line of the plan views, Fig. 130. Then draw a perpendicular ZZ' to MN.

In delineating the pyramid, it is necessary, in the first place, to construct the plan. The point S', where the line ZZ' intersects the line MN, is to be taken as the center of the figure, and from this point, with a radius equal to the side of the hexagon which forms the base of the pyramid, describe a circle, cutting MN in A' and D'. From these points, with the same radius, draw four arcs of circles, cutting the primary circle in four points. These six points being joined by straight lines, will form the figure $A' B' C' D' E' F'$,

which is the base of the pyramid; and the lines $A' D'$, $B' E'$, and $C' F'$, will represent the projections of its edges foreshortened as they would appear in the plan. If this operation has been correctly performed, the opposite sides of the hexagon should be parallel to each other and to one of the diagonals; this should be tested by the application of the square or other instrument proper for the purpose.

By the help of the plan obtained as above described, the vertical

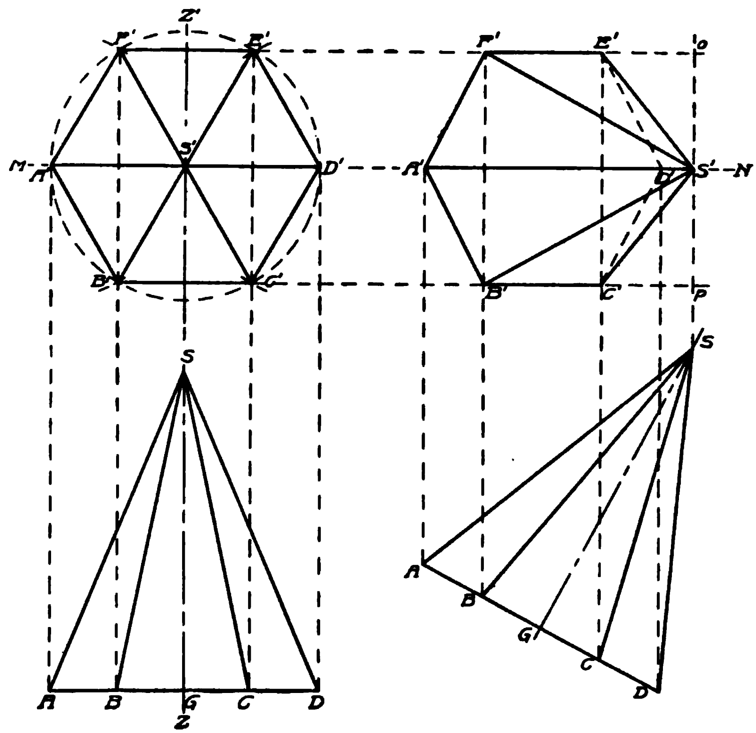


Fig. 130. Construction of Regular Hexagonal Pyramid

projection of the pyramid may be easily constructed. Since it is directly under the plan, it must be projected vertically downward; therefore, from each of the points A', B', C', drop perpendiculars to AD, the base line of the pyramid in the elevation. The points of intersection, A, B, C, and D, are the true positions of all the angles of the base; and it only remains to determine the height of the pyramid, which is to be set off from the point G to S, and to

draw SA, SB, SC, and SD, which are the only edges of the pyramid visible in the elevation. Of these it is to be remarked that SA and SD alone, being parallel to the vertical plane, are seen in their true length; and, moreover, that from the assumed position of the solid under examination, the points F' and E' being situated in the lines BB' and CC', the lines SB and SC are each the projections of two edges of the pyramid.

2. *Construct the projections of the pyramid, Example 1, having its base set in an inclined position, but with its edges SA and SD still parallel to the vertical plane,* Fig. 130.

It is evident, that with the exception of the inclination, the vertical projection of this solid is precisely the same as in the preceding example, and it is only necessary to show the same view of the pyramid in its new position. For this purpose, after having fixed the position of the point D, draw through this point a straight line DA, making with MN an angle equal to the desired inclination of the base of the pyramid. Then set off the distance DA, equal to that used in Example 1; erect a perpendicular on the center, and set off GS equal to the height of the pyramid. Transfer also from the first example the distance BG and CG to the corresponding points, and complete the figure by drawing the straight lines AS, BS, CS, and DS.

In constructing the plan of the pyramid in this position, it is to be remarked that since the edges SA and SD are still parallel to the vertical plane, and the point D remains unaltered, the projection of the points A, D, and S, will still be in the line MN. The position of A' is determined by the intersection of the perpendicular AA' with MN. The remaining points, B', C', etc., in the projection of the base, are found, in a similar manner, by the intersections raised from the corresponding points in the elevation, with lines drawn parallel to MN, at a distance (set off at o, p) equal to the width of the base. By joining all the contiguous points, the figure $A'B'C'D'E'F'$ is obtained representing the horizontal projection of the base, two of its sides, however, being dotted, as they must be supposed to be concealed by the body of the pyramid. The vertex S having been similarly projected to S', and joined by straight lines to the several angles of the base, the projection of the solid is completed.

INTERSECTIONS

If one surface meets another at some angle, an intersection is produced. Either surface may be plane, or curved. If both are plane, the intersection is a straight line; if one is curved, the intersection is a curve, except in a few special cases; and if both are curved, the intersection is usually curved. In the latter case, the

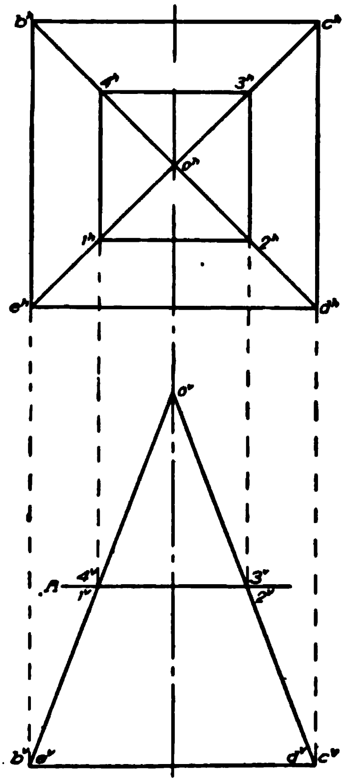


Fig. 131. Intersection of Plane and Pyramid

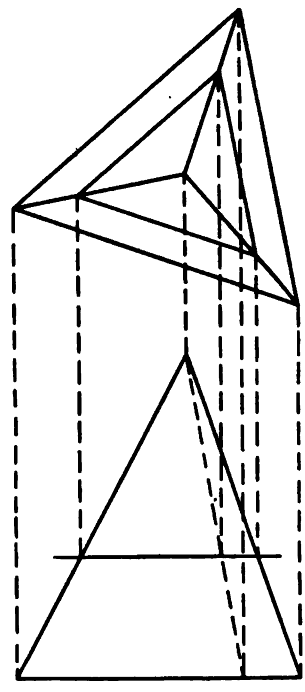


Fig. 132. Intersection of Plane and Pyramid

entire curve does not always lie in the same planes. If all points of any curve lie in the same plane, it is called a *plane curve*. A plane intersecting a curved surface must always give either a plane curve or a straight line.

Planes with Planes. In Fig. 131 a square pyramid is cut by a plane A parallel to the horizontal. This plane cuts from the pyra-

mid a four-sided figure, the four corners of which will be the points where A cuts the four slanting edges of the solid. The plane intersects edge ob at point 4^v in elevation. This point must be found in plan vertically above on the horizontal projection of line ob, that is, at point 4^h. Edge oe is directly in front of ob, so is shown in elevation as the same line, and plane A intersects oe at point 1^v in

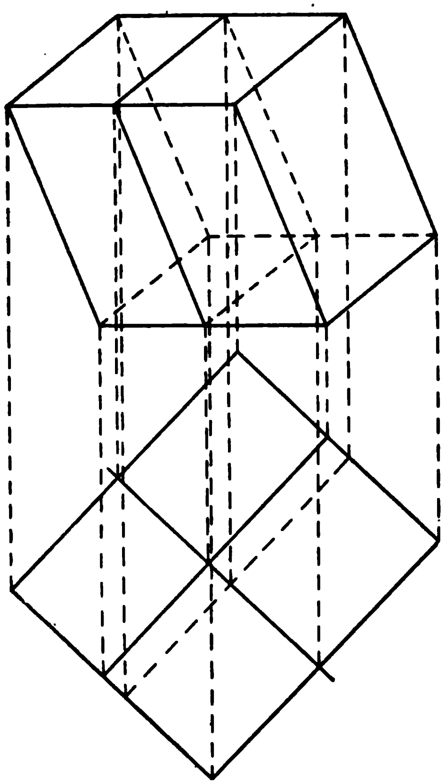


Fig. 133. Intersection of Plane and Prism

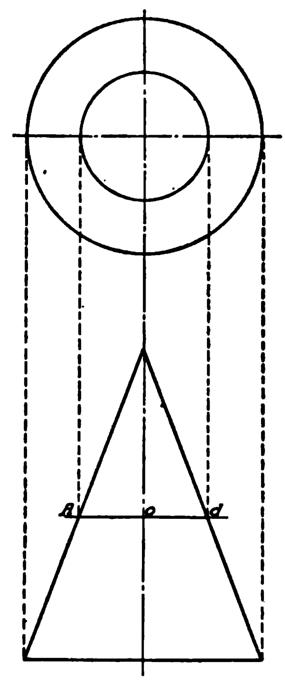


Fig. 134. Intersection of Plane and Cone

elevation, found in plan at 1^h. Points 3 and 2 are obtained in the same way. The intersection is shown in plan as the square 1-2-3-4, which is also its true size as it is parallel to the horizontal plane. In a similar way the intersections are found in Figs. 132 and 133. It will be seen that in these three cases where the planes are parallel to the bases, the sections are of the same shape as the bases, and have their sides parallel to the edges of the bases.

It is an invariable rule that when such a solid is cut by a plane parallel to its base, the section is a figure of the same shape as the base. If then in Fig. 134 a right cone is intersected by a plane parallel to the base the section must be a circle, the center of which in plan coincides with the apex. The radius must equal *od*.

In Fig. 135 and Fig. 136 the cutting plane is not parallel to the base, hence the section will not be of the same shape as the base.

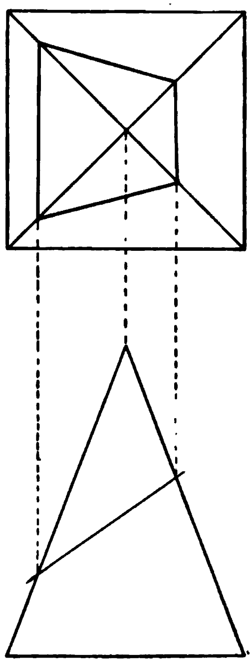


Fig. 135. Intersection of Plane and Square Pyramid

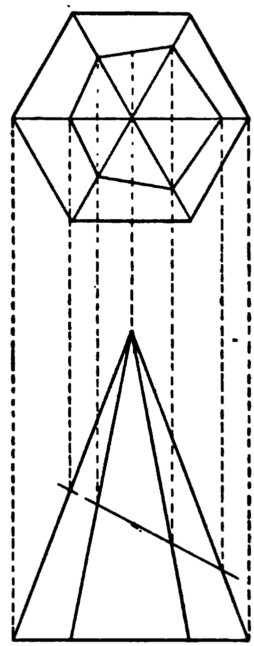


Fig. 136. Intersection of Plane and Hexagonal Pyramid

The intersections are found, however, in exactly the same manner as in the previous figures, by projecting the points where the plane intersects the edges in elevation, on to the other view of the same line.

ILLUSTRATIVE EXAMPLES

1. Find the horizontal projection of a transverse section of the pyramid of Fig. 130, made by a plane perpendicular to the vertical, but inclined at an angle to the horizontal plane of projection; and let all the sides of the base be at an angle with $M\,N$, Fig. 137.

Having drawn the vertical SS', the center line of the figures, its point of intersection with the line MN is the center of the plan. Since none of the sides of the base are to be parallel with MN, draw a diameter $A'D'$ making the required angle with MN, and from the points A' and D' proceed to set out the angular points of the hexagon, as in Fig. 130. Then join the angular points which are diametrically opposite and project the figure thus obtained upon the vertical plane, as shown.

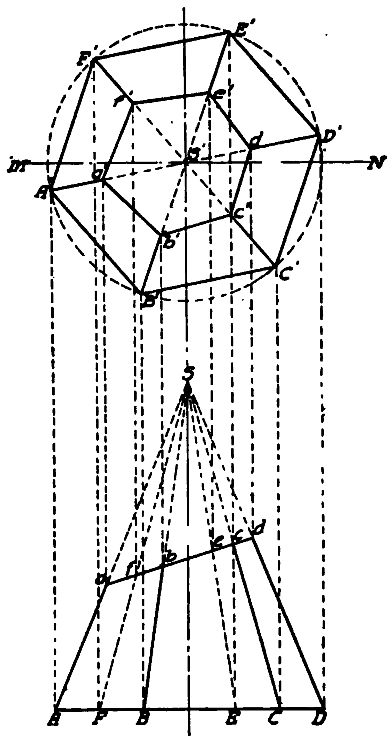


Fig. 137. Frustum of Hexagonal Pyramid

Now, if the cutting plane be represented by the line ad in the elevation, it is obvious that it will expose, as the section of the pyramid, a polygon whose angular points being the intersections of the various edges with the cutting plane, will be projected in perpendiculars drawn from the points where it meets these edges respectively. From the points a, f, b, etc., raise the perpendiculars aa', ff', bb', etc., to meet the lines $A'D'$, $F'C'$, $B'E'$, etc. When the contiguous points of intersection of these lines are joined, a six-sided figure will be formed which will represent the section required. The edges FS and ES being concealed in the elevation, but necessary for the construction of the plan, have been expressed in dotted lines, as is also the portion of the pyramid situated above the cutting plane which, though supposed to be removed, is necessary in order to draw the lines representing the edges.

2. Find the horizontal projection of the transverse section of a regular five-sided pyramid, cut by a plane perpendicular to the vertical, but inclined at an angle to the horizontal plane of projection; and let one edge of the pyramid, BS, be in a plane

perpendicular to both the horizontal and the vertical planes of projection, as shown in Fig. 138.

The plan of the pyramid is constructed by describing from the center S' a circle circumscribing the base, and from B' dividing the circumference into five equal parts, and joining the contiguous points of division by straight lines. These form the polygon $A' B' C' D' E'$, whose angles, when joined to the center S', show the projections of the edges of the pyramid. Then, following the method above explained, the elevation and the horizontal projection of the section made by the plane ac are obtained. But that method will not suffice for the determination of the point b', because the perpendicular let fall from the corresponding point b, in the elevation, coincides with the projection of the edge BS. Let the pyramid supposedly be turned a quarter of a revolution round its axis; the line $B'S'$ will then have assumed the position $S' b^2$. Project the point b^2 to b^3, and join $S b^3$. Then since the required point must also be conceived to have described a quarter of a circle in a plane parallel to the horizontal plane, and that its new position must be in the line $S b^3$, it is obvious that its vertical projection is the point b^4, the intersection of a horizontal line drawn through b with the line $S b^3$. The distance $b b^4$ may then be used to determine the distance from S' to b', and determines the position of the latter point in the plan; or, following a more methodical process, by projecting the point b^4 to b^5, and describing a circle from the center S' passing through b^5, its intersection with $B'S'$ is the point sought.

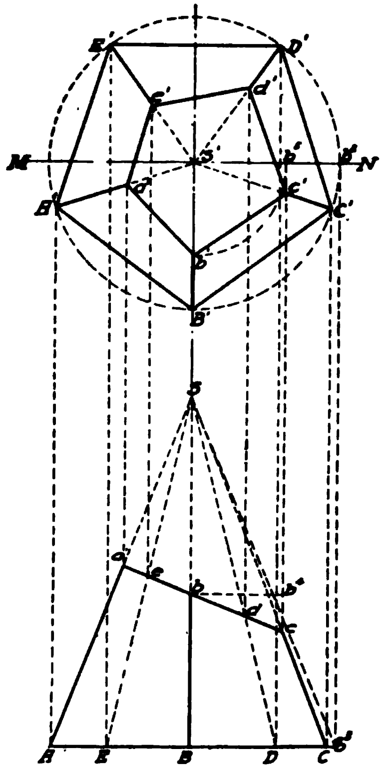


Fig. 138. Frustum of Pentagonal Pyramid

Planes with Cones or Cylinders. Sections cut by a plane from a cone have already been defined as *conic sections*. These sections may be any of the following: two straight lines, circle, ellipse, parabola, hyperbola. All except the parabola and hyperbola may also be cut from a cylinder.

Methods have previously been given for constructing the ellipse, parabola, and hyperbola, without projections; it will now be shown that they may be obtained as actual intersections.

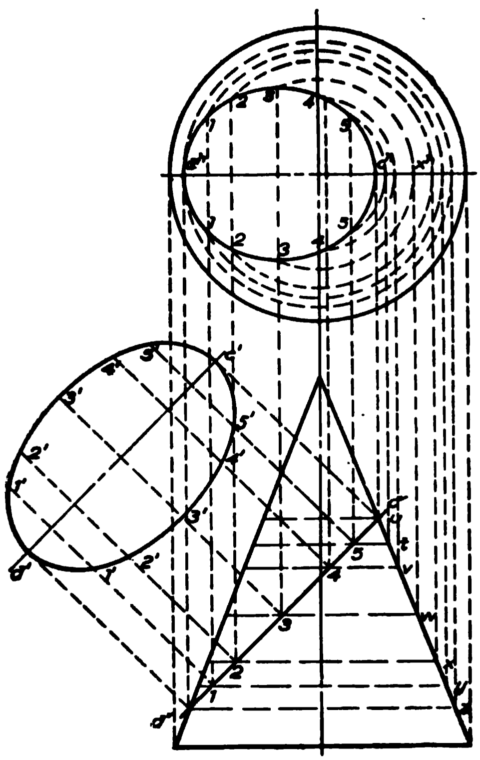


Fig. 139. Ellipse—Section from a Cone

Ellipse. In Fig. 139 the plane cuts the cone obliquely. To find points on the curve in plan take a series of horizontal planes $x\,y\,z$, etc., between points c^v and d^v. One of these planes, as w, should be taken through the center of cd. The points c and d must be points on the curve, since the plane cuts the two contour elements at these points. Contour elements are those forming the outline. The horizontal projections of the contour elements will be found in a horizontal line passing through the center of the base; hence the horizontal projection of c and d will be found on this center line, and will be the extreme ends of the curve.

The plane x cuts the surface of the cone in a circle, as it is parallel to the base, and the diameter of the circle is the distance between the points where x crosses the two contour elements. This circle, lettered x on the plan, has its center at the horizontal projection of the apex. The circle x and the curve cut by the plane are both on

the surface of the cone, and their vertical projections intersect at the points 2-2. Point 2 on the elevation then represents two points which are shown in plan directly above on the circle x, and are points on the required intersection. Planes y and z, and as many more as may be necessary to determine the curve accurately, are used in the same way. The curve found is an ellipse. The student will readily see that the true size of this ellipse is not shown in the plan, for the plane containing the curve is not parallel to the horizontal.

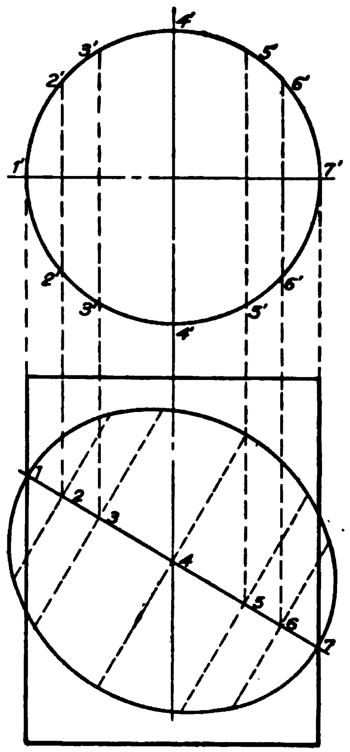


Fig. 140. Ellipse—Section from a Cylinder

In order to find the *actual size of the ellipse*, it is necessary to place its plane in a position parallel either to the vertical or to the horizontal. The actual length of the long diameter of the ellipse must be shown in elevation, c^vd^v, because the line is parallel to the vertical plane. The plane of the ellipse then may be revolved about c^vd^v as an axis until it becomes parallel to V, when its true size will be shown. For the sake of clearness of construction, c^vd^v is imagined moved over to the position $c'd'$, parallel to c^vd^v. The lines 1-1, 2-2, 3-3 on the plan show the true width of the ellipse, as these lines are parallel to H, but are projected closer together than their actual distances. In elevation these lines are shown as the points 1, 2, 3, at their true distance apart. Hence if the ellipse is revolved around its axis c^vd^v, the distances 1-1, 2-2, 3-3 may be laid off on lines perpendicular to c^vd^v, and the true size of the figure be shown.

In Fig. 140 a plane cuts a cylinder obliquely. This is a simpler case, as the horizontal projection of the curve coincides with the base of the cylinder. To obtain the true size of the section, which is an ellipse, any number of points are assumed on the plan and

projected down on the cutting plane, at 1, 2, 3, etc. The lines drawn through these points perpendicular to 1′-7′ are made equal in length to the corresponding distances 2′-2′, 3′-3′, etc., on the plan, because 2′-2′ is the true width of curve at 2.

Parabola. If a cone is intersected by a plane which is parallel to only one of the elements, as in Fig. 141, the resulting curve is

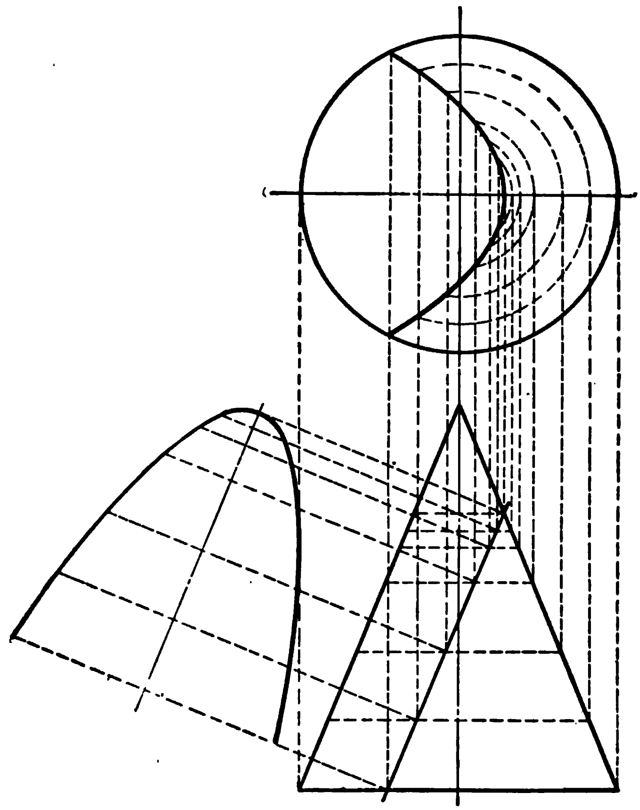


Fig. 141. Parabola—Section from a Cone

the *parabola*, the construction of which is exactly similar to that for the ellipse, as given in Fig. 139. If the intersecting plane is parallel to more than one element, or is parallel to the axis of the cone, a hyperbola is produced.

In Fig. 142, the vertical plane A is parallel to the axis of the cone. In this instance the curve when found will appear in its true

size, as plane A is parallel to the vertical. Observe that the highest point of the curve is found by drawing the circle X on the plan tangent to the given plane. One of the points where this circle crosses the diameter is projected down to the contour element of the cone, and the horizontal plane X drawn. Intermediate planes Y, Z, etc., are chosen, and corresponding circles drawn in plan. The points where these circles are crossed by the plane A are points on the curve, and these points are projected down to the elevation on the planes Y, Z, etc.

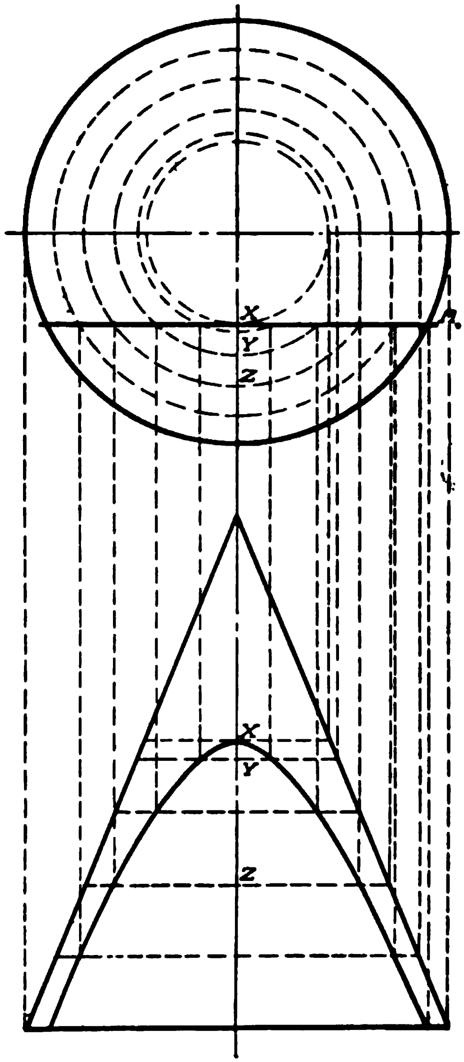


Fig. 142. Hyperbola—Section from a Cone

DEVELOPMENT OF SURFACES

General Details of Process. A surface may be considered as formed by the motion of a line. Any length of line moved sidewise in any direction will form a surface, of a width equal to the length of the line, and of a length equal to the distance over which the line is moved. There are two different classes of surfaces; namely, those formed by a moving straight line, and those formed by a moving curved line.

In some construction work, patterns of different faces or of the whole surface must be made; in stone cutting, for example,

there must be a pattern giving the shape of any irregular surface, and in sheet-metal work a pattern must be made such that, when a sheet is cut, it can be so formed that it will be of the same shape as the original object.

This pattern making, or the laying out of a complete surface on one plane, is called the development of the surface. Any surface

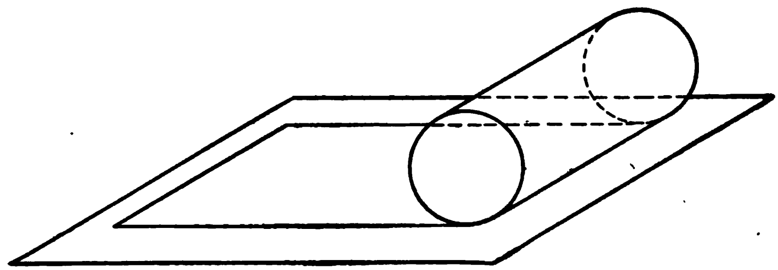


Fig. 143. Development of a Right Cylinder Rolled Out on a Plane

which can be smoothly wrapped about by a sheet of paper, can be developed. Figures made up of planes and single curved surfaces only would be of this nature. Double curved surfaces and warped surfaces cannot be developed, and patterns of such surfaces, when desired, must be made by an approximate method which requires two or more pieces to make the complete pattern.

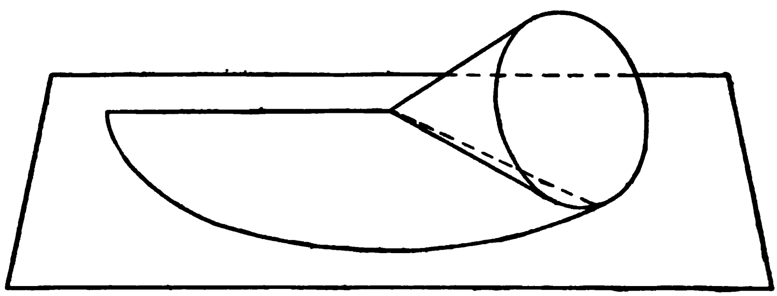


Fig. 144. Development of a Right Cone Rolled Out on a Plane

By finding the true size of all the faces of an object made up of planes, and joining them in order at their common edges, the developed surface will be formed. The best way to do this is to find the true length of the edges of the object.

Right Cylinder. In Fig. 143 is represented a right cylinder rolling on a plane. The development is formed by one complete

revolution of the cylinder and is a rectangle, the width being equal to the height of the cylinder and the length to the circumference.

Right Cone. In Fig. 144 is represented a right cone rolling out its development, which is a sector of a circle. The arc equals the circumference of the circle forming the base of the cone, and the radius equals the slant height.

The projections of any object must be drawn before the development can be made, but it is necessary only to draw such views as are required for finding the lengths of elements, and true sizes of cut surfaces.

Rectangular Prism. In order to find the development of the rectangular prism in Fig. 145, the back face, 1-2-7-6, is supposed

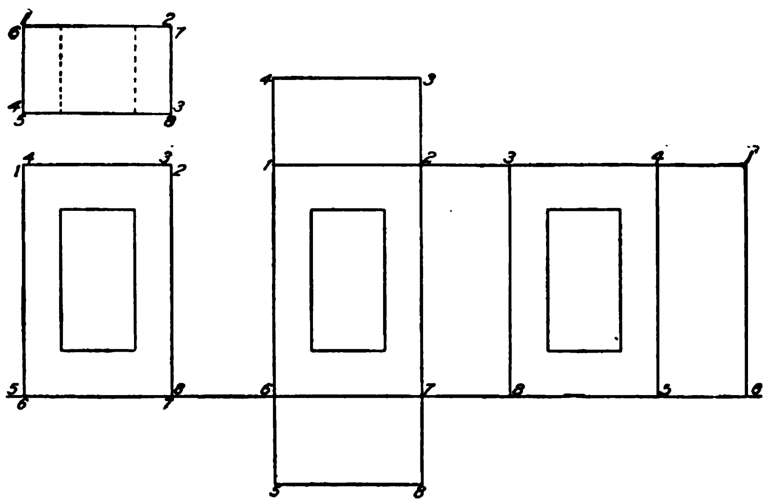


Fig. 145. Development of Hollow Rectangular Prism

to be placed in contact with some plane, then the prism turned on the edge 2-7 until the side 2-3-8-7 is in contact with the same plane, and this process continued until all four faces have been placed on the same plane. The rectangles 1-2-3-4 and 6-7-8-5 are for the top and bottom, respectively. The development then is the exact size and shape of a covering for the prism. If a rectangular hole is cut through the prism, the openings in the front and back faces will be shown in the development in the centers of the two broad faces.

The development of a right prism, then, consists of as many rectangles joined together as the prism has sides, these rectangles being the exact size of the faces of the prism, and in addition two polygons the exact size of the bases. It will be found helpful in developing a solid to number or letter all of the corners on the projections, then designate each face when developed in the same way as in the figure.

Cone. If a cone be placed on its side on a plane surface, one element will rest on the surface. If now the cone be rolled on the

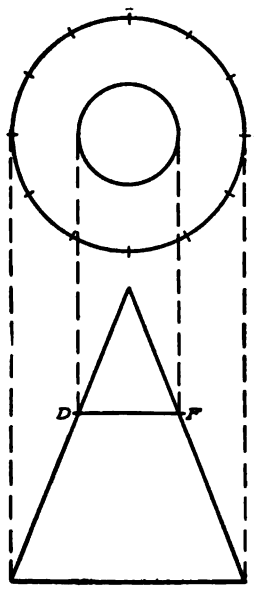


Fig. 146. Plan and Elevation of Cone

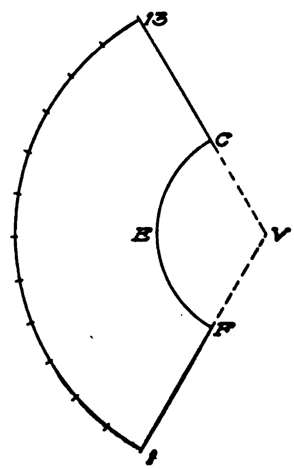


Fig. 147. Development of Cone

plane, the vertex remaining stationary until the same element is in contact again, the space rolled over will represent the development of the convex surface of the cone. Fig. 146 is a cone cut by a plane parallel to the base. In Fig. 147, let the vertex of the cone be placed at V, and one element of the cone coincide with $VF1$. The length of this element is taken from the elevation, Fig. 146, of either contour element. All of the elements of the cone are of the same length, so that when the cone is rolled, each point of the base as it touches the plane will be at the same distance from the vertex. From this it follows that in the development of the base,

the circumference will become the arc of a circle of radius equal to the length of an element, and of a length equal to the distance around the base. To find this length divide the circumference of the base in the plan into any number of equal parts, say twelve, and lay off twelve such spaces, 1 . . . . 13 along an arc drawn with radius equal to $V1$; join 1 and 13 with V, and the resulting sector is the development of the cone from vertex to base. In order to represent on the development the circle cut by the section plane DF, draw, from the vertex V as a center and with VF as a radius, the arc FC. The development of the frustum of the cone will be a portion of a circular ring. This of course does not include the development of the bases, which would be simply two circles the same sizes as shown in plan.

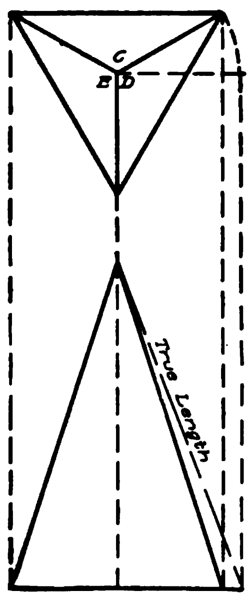


Fig. 148. Plan and Elevation of Triangular Pyramid

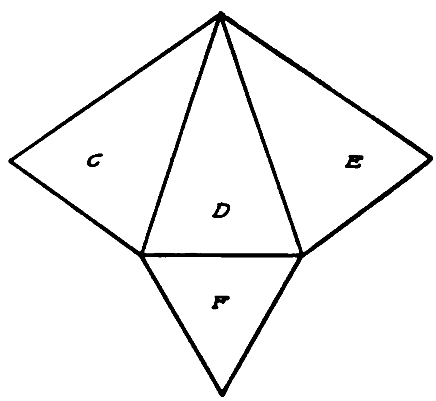


Fig. 149. Development of Triangular Pyramid

Regular Triangular Pyramid. Fig. 148 represents the plan and elevation of a regular triangular pyramid, and Fig. 149 its development. If face C is placed on the plane its true size will be shown in the development. The true length of the base of triangle C is shown in the plan. As the slanting edges, however, are not parallel to the vertical, their true length is not shown in elevation but must be obtained by the method given on page 16, as indicated in Fig. 148. The triangle may now be drawn in its full size at C in the development, and as the pyramid is regular, two other equal triangles,

D and *E*, may be drawn to represent the other sides. These, together with the base *F*, constitute the complete development.

Truncated Circular Cylinder. If a truncated circular cylinder is to be developed, or rolled upon a plane, the elements, being parallel, will appear as parallel lines, and the base line being perpendicular to the elements, will appear as a straight line of length equal to the circumference of the base. The base of the cylinder in Fig. 150 is divided into twelve equal parts, 1, 2, 3, etc., and commencing at point 1 on the development, these twelve equal spaces are laid off along the straight line, giving the total width.

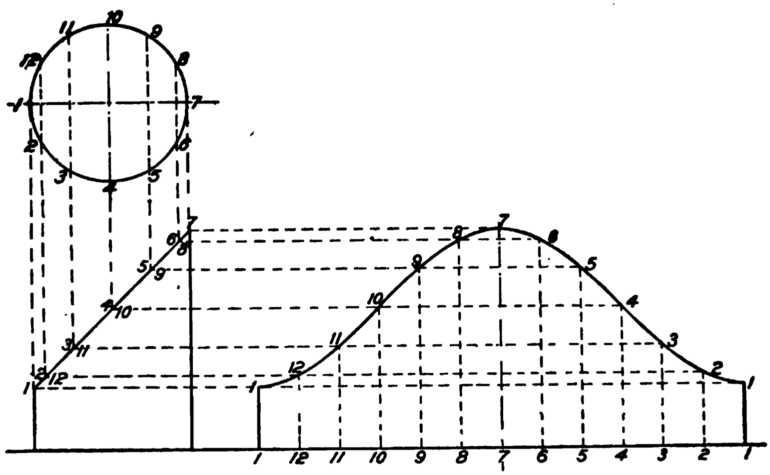


Fig. 150. Projections and Development of Truncated Cylinder

Draw in elevation the elements corresponding to the various divisions of the base, and note the points where they intersect the oblique plane. As the cylinder is rolled beginning at point 1, the successive elements, 1, 12, 11, etc., will appear at equal distances apart, and equal in length to the lengths of the same elements in elevation. Thus point number 10 on the development is found by projecting horizontally across from 10 in elevation. It will be seen that the curve formed is symmetrical, the half on the left of 7 being similar to that on the right. The development of any similar surface may be found in the same manner.

The principle of cylinder development is used in laying out elbow joints, pipe ends cut off obliquely, etc. In Fig. 151 is shown

plan and elevation of a three-piece elbow and collar, and developments of the four pieces. In order to construct the various parts making up the joint, it is necessary to know what shape and size must be marked out on the flat sheet metal so that when cut out and rolled up the three pieces will form cylinders with the ends fitting together as required. Knowing the kind of elbow desired, first draw the plan and elevation, and from these make the develop-

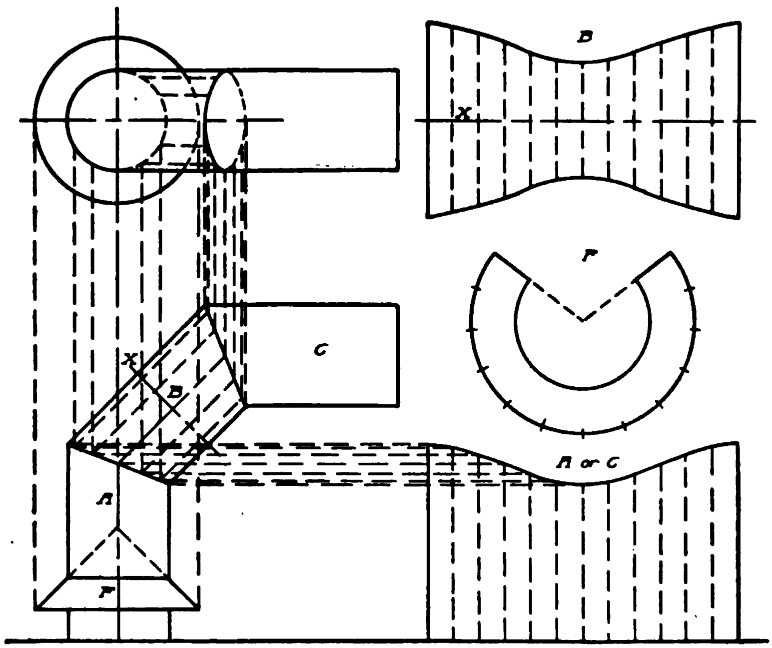


Fig. 151. Plan, Elevation, and Development of Three-Piece Elbow and Collar

ments. Let the lengths of the three pieces A, B, and C be the same on the upper outside contour of the elbow, the piece B at an angle of 45 degrees; the joint between A and B bisects the angle between the two lengths, and in the same way the joint between B and C. The lengths A and C will then be the same and one pattern will answer for both. The development of A is made exactly as just explained for Fig. 150, and this is also the development of C.

It should be borne in mind that in developing a cylinder the base must always be at right angles to the elements, and if the cylinder as given does not have such a base, it becomes necessary

to cut the cylinder by a plane perpendicular to the elements, and use the intersection as a base. This point must be clearly understood in order to proceed intelligently. A section at right angles to the elements is the only section which will unroll in a straight line, and is, therefore, the section from which the other sections must be developed. As *B*, Fig. 151, has neither end at right angles to its length, the plane *X* is drawn at the middle and perpendicular to the length. *B* has the same diameter as *C* and *A*, so the section cut by *X* will be a circle of the same diameter as the base of *A*, and is shown in the development at *X*.

The elements on *B* are drawn from the points where the elements on the elevation of *A* meet the joint between *A* and *B*, and are equally spaced as shown on the plan of *A*. Commencing with the left-hand element in *B*, the length of the upper element between *X* and the top corner of the elbow is laid off above *X*, giving the first point in the development of the end of *B* fitting with *C*. The lengths of the other elements in the elevation of *B* are measured in the same way and laid off from *X*. The development of the other end of the piece *B* is laid off below *X*, using the same distances, since *X* is half way between the ends. The development of the collar is simply the development of the frustum of a cone, which has already been explained, Fig. 147. The joint between *B* and *C* is shown in plan as an ellipse, the construction of which the student should be able to understand from a study of the figure.

ISOMETRIC PROJECTION

Isometric of a Cube. In orthographic projection an object has been represented by two or more projections; another system, called isometrical drawing, is often used to show in one view the three dimensions of an object, length (or height), breadth, and thickness. An isometrical drawing of an object, as a cube, is called for brevity the isometric of the cube.

To obtain a view which shows the three dimensions in such a way that measurements may be taken from them, draw the cube in the simple position shown at the left, Fig. 152, with two faces parallel to *V;* the diagonal from the front upper right-hand corner to the back lower left-hand corner is indicated by the dotted line. Swing the cube around until the diagonal is parallel with *V*, as shown in the

second position. Here the front face is at the right. In the third position the lower end of the diagonal has been raised so that it is parallel to H, becoming thus parallel to both planes. The plan is found by the principles of projection, from the elevation and the preceding plan. The front face is now the lower of the two faces shown in the elevation. From this position the cube is swung around, using the corner as a pivot, until the diagonal is perpendicular to V but still parallel to H. The plan remains the same, except as regards position; while the elevation, obtained by projecting across from the previous elevation, gives the isometrical projection of the cube. The front face is now at the left.

Distinction between Isometric Projection and Isometric Drawing. In the last position, as one diagonal is perpendicular to V, it follows

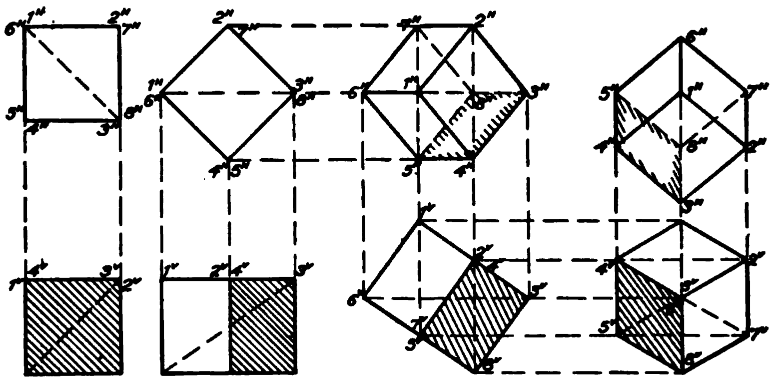


Fig. 152. Development of an Isometric of a Cube

that all the faces of the cube make equal angles with V, hence are projected on that plane as equal parallelograms. For the same reason all the edges of the cube are projected in elevation in equal lengths, but, being inclined to V, appear shorter than they actually are on the object. Since they are all equally foreshortened and since a drawing may be made at any scale, it is customary to make all the isometrical lines of a drawing full length. This will give the same proportions, and is much the simpler method. Herein lies the distinction between an isometric projection and an isometric drawing.

It will be noticed that the figure may be inscribed in a circle, and that the outline is a perfect hexagon. Hence the lines showing

breadth and length are 30-degree lines, while those showing height are vertical.

True Length of Lines. Fig. 153 shows the isometric of a cube 1 inch square. All of the edges are shown in their true length, hence

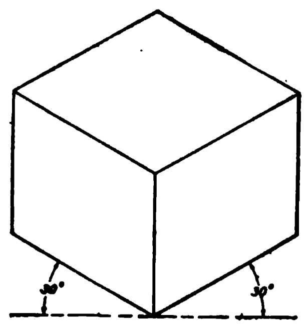


Fig. 153. Isometric of a Cube

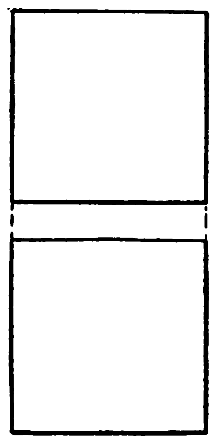


Fig. 154. Plan and Elevation of a Cube

all the surfaces appear of the same size. In the figure the edges of the base are inclined at 30 degrees with a T-square line, but this is not always the case. For rectangular objects, such as prisms, cubes, etc., the base edges are at 30 degrees only when the prism or cube is supposed to be in the simplest possible position. The cube in Fig. 153 is supposed to be in the position indicated by plan and elevation in Fig. 154, that is, standing on its base, with two faces parallel to the vertical plane.

If the isometric of the cube in the position shown in Fig. 155 were required, it could not be drawn with the base edges at 30 degrees; neither would these edges appear in their true lengths. It

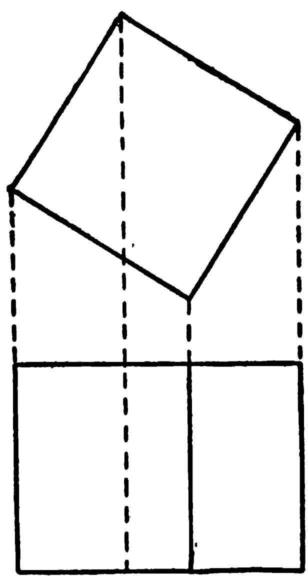


Fig. 155. Cube of Fig. 154 Rotated 30 Degrees with Vertical Plane

follows, then, that in isometrical drawing, true lengths appear only as 30-degree lines or as vertical lines. Edges or lines that in actual projection are either parallel to a T-square line or perpendicular to V, are drawn in isometric as 30-degree lines, full length; and those that are actually vertical are made vertical in isometric, also full length.

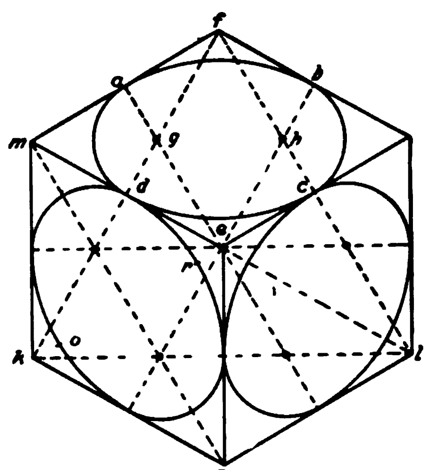


Fig. 156. Isometric of a Cube with Circles Inscribed on its Faces

Three Isometric Axes. In Fig. 152, lines such as the front vertical edges of the cube and the two base edges are called the *three isometric axes*. The isometric of objects in oblique positions, as in Fig. 155, can be constructed only by reference to their projections, by methods which will be explained in the section on "Oblique Projection", page 123.

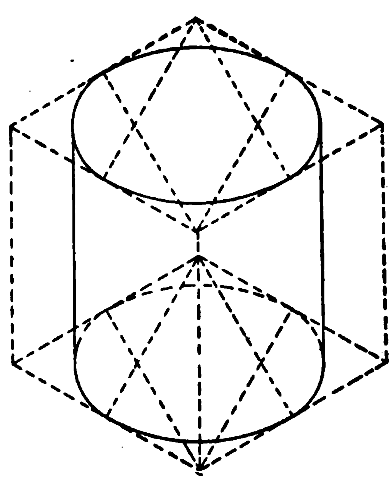


Fig. 157. Isometric of a Cylinder

Applications of Isometric Projections. In isometric drawing small rectangular objects are more satisfactorily represented than large curved ones. In woodwork, mortises and joints and various parts of framing are well shown in isometric. This system is used also to give a kind of bird's-eye view of mills or factories. It is also used in making sketches of small rectangular pieces of machinery, where it is desirable to give shape and dimensions in one view.

Characteristics of Various Isometrics. *Cube with Inscribed Circles.* Fig. 156 shows a cube with circles inscribed in the top and two side faces. The isometric of a circle is an ellipse, the

exact construction of which would necessitate finding a number of points; for this reason an approximate construction by arcs of circles is often made. In the method, Fig. 156, four centers are used. Considering the upper face of the cube, lines are drawn from the obtuse angles *f* and *e* to the centers of the opposite sides. The intersections of these lines give points *g* and *h*, which serve as centers for the ends of the ellipse. With *g* as center and radius *ga*, the arc *ad* is drawn, and with *f* as center and radius *fd*, the arc

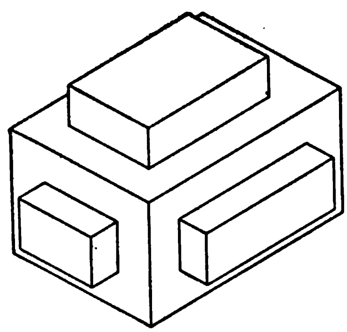


Fig. 158. Isometric of a Wooden Block

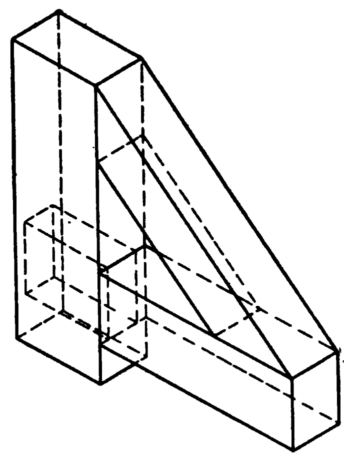


Fig. 159. Isometric of a Wooden Brace

dc is drawn; the ellipse is finished by using centers *h* and *e*. This construction is applied to all three faces.

Cylinder. Fig. 157 is the isometric of a cylinder standing on its base.

Blocks. Fig. 158 represents a block with smaller blocks projecting from three faces.

Framework. Fig. 159 shows a framework of three pieces, two at right angles and a slanting brace. The horizontal piece is mortised into the upright as indicated by the dotted lines.

House. In Fig. 160 the isometric outline of a house is represented, showing a dormer window and a partial hip roof; *ab* is a hip rafter, *cd* a valley. Let the pitch of the main roof be shown at *B*, and let *m* be the middle point of the top of the end wall of the house. Then, by measuring vertically up a distance *ml* equal to the vertical

height *an* shown at *B*, a point on the line of the ridge will be found at *l*. Line *li* is equal to *b h*, and *i h* is then drawn. Let the pitch of the end roof be given at *A*. This shows that the peak of the roof, or the end *a* of the ridge, will be back from the end wall a distance equal to the base of the triangle at *A*. Hence, lay off from *l* this distance, giving point *a*, and join *a* with *b* and *x*.

The height *k e* of the ridge of the dormer roof is known, and it must be found where this ridge will meet the main roof. The ridge must be a 30-degree line as it runs parallel to the end wall of the house and to the ground. Draw from *e* a line parallel to *b h* to meet a vertical through *h* and *f*. This point is in the vertical plane of

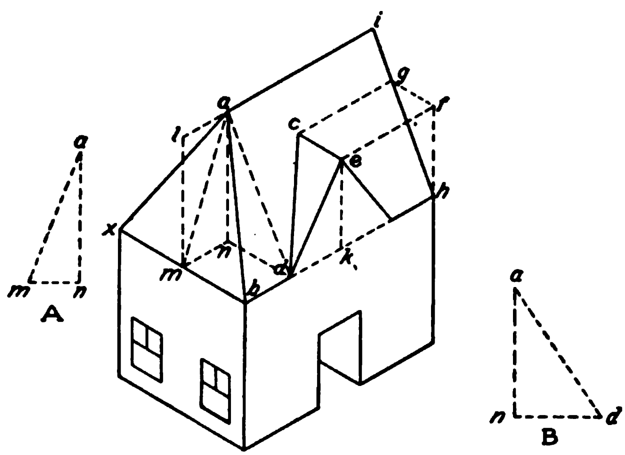


Fig. 160. Isometric Outline of a House

the end wall of the house, hence in the plane of *i h*. If now a 30-degree line be drawn from *f* parallel to *x b*, it will meet the roof of the house at *g*. The dormer ridge and *f g* are in the same horizontal plane, hence will meet the roof at the same distance below the ridge *a i*. Therefore draw the 30-degree line *g c*, and connect *c* with *d*.

Box with Cover. In Fig. 161 a box is shown with the cover opened through 150 degrees. The right-hand edge of the bottom shows the width, the left-hand edge shows the length and the vertical edge shows the height. The short edges of the cover are not isometric lines, hence are not shown in their true lengths; neither is the angle through which the cover is opened represented in its actual size.

The corners of the cover must then be determined by co-ordinates from an end view of the box and cover. As the end of the cover

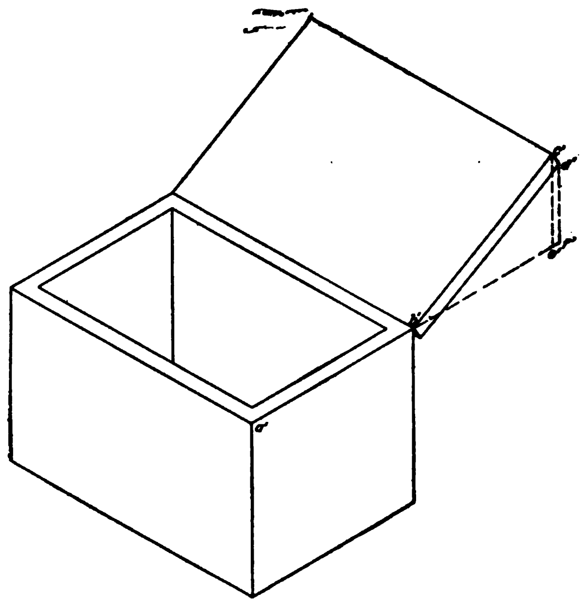


Fig. 161. Isometric of a Box and Cover

is in the same plane as the end of the box, the simple end view as shown in Fig. 162 will be sufficient. Extend the top of the box to the right, and from *c* and *d* let fall perpendiculars on *ab* produced, giving the points *e* and *f*. The point *c* may be located by means of the two distances or co-ordinates *be* and *ec*, and these distances will appear in their true lengths in the isometric view. Hence produce *a′b′* to *e′* and *f′*; and from these points draw verticals *e′c′* and *f′d′*; make *b′e′* equal to *be*, *e′c′* equal to *ec*; and similarly for *d′*. Draw the lower edge parallel to *c′d′* and equal to it in length, and connect with *b′*.

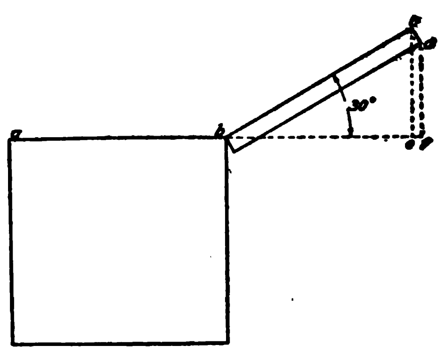


Fig. 162. End View of Box Shown in Fig. 161

It will be seen that in isometric drawing parallel lines always appear parallel. It is also true that lines divided proportionally maintain this same relation in isometric drawing.

Prism with Semicircular Top. Fig. 163 shows a block or prism with a semicircular top. Find the isometric of the square circumscribing the circle, then draw the curve by the approximate method. The centers for

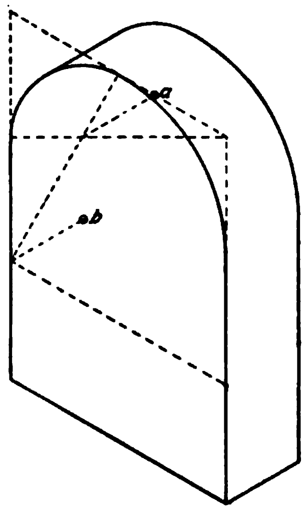


Fig. 163. Isometric of a Prism with Semicircular Top

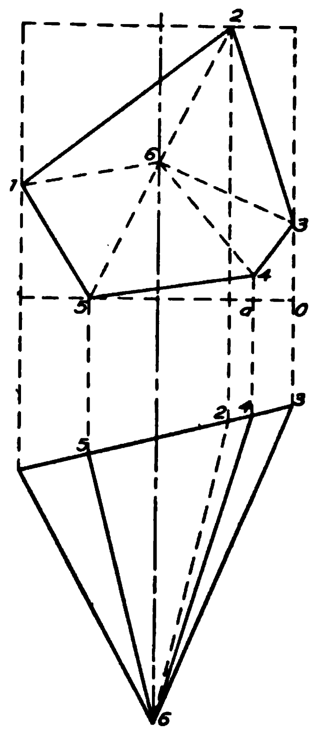


Fig. 164. Plan and Elevation of Oblique Pentagonal Pyramid

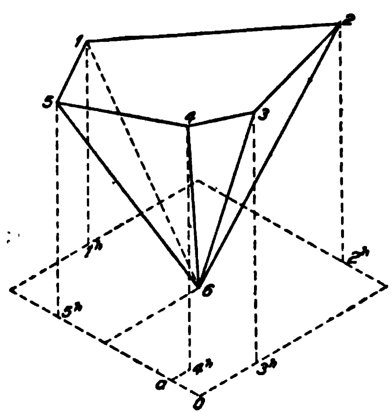


Fig. 165. Isometric of Fig. 164

the back face are found by projecting the front centers back 30 degrees equal to the thickness of the prism, as shown at *a* and *b*.

Pyramid. The plan and elevation of an oblique pentagonal pyramid are shown in Fig. 164. It is evident that none of the edges

of the pyramid can be drawn in isometric as either vertical or 30-degree lines; hence a system of co-ordinates must be used as shown in Fig. 165. This problem illustrates the most general case; and to locate some of the points three co-ordinates must be used, two at 30 degrees and one vertical.

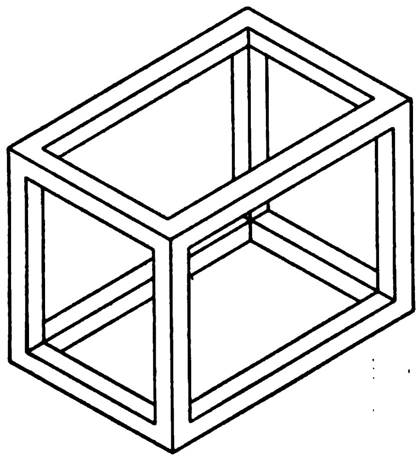


Fig. 166. Isometric of a Skeleton of a Box

Circumscribe, about the plan of the pyramid, a rectangle which shall have its sides respectively parallel and perpendicular to a T-square line.

The isometric of this rectangle can be drawn at once with 30-degree lines, as shown in Fig. 165, *o* being the same point in both figures. The horizontal projection of point 3 is found in isometric at 3^h, at the same distance from *o* as in the plan. That is, *any distance which in plan is parallel to a side of the circumscribing rectangle, is shown in isometric in its true length and parallel to the corresponding side of the isometric rectangle.* If point 3 were on the horizontal plane its isometric would be 3^h, but the point is at the vertical height above *H* given in the elevation; hence, lay off above 3^h this vertical height, obtaining the actual isometric of the point. To locate point 4, draw $4a$ parallel to the side of the rectangle; they lay off oa and $a4^h$, giving what may be called the isometric plan of 4. The

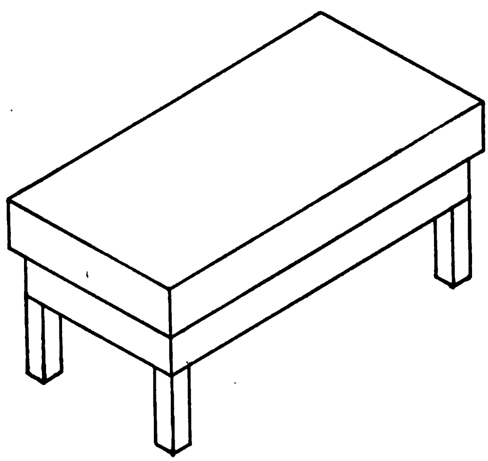


Fig. 167. Isometric of a Carpenter's Bench

vertical height taken from the elevation locates the isometric of the point.

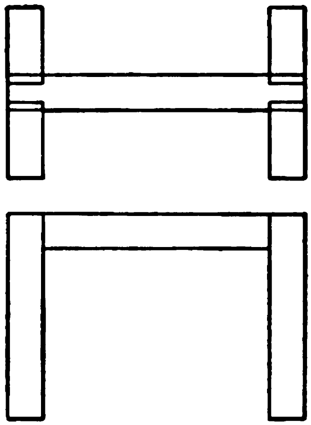


Fig. 168. Plan and Elevation of Sawhorse

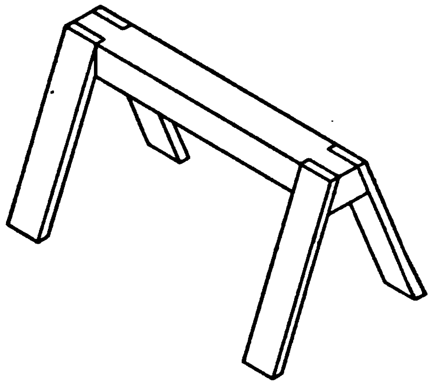


Fig. 169. Isometric of Fig. 168

In like manner all the corners of the pyramid, including the apex, are located. The rule is, *locate first in isometric the horizontal*

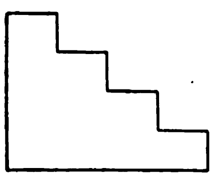


Fig. 170. End Elevation of Stairs

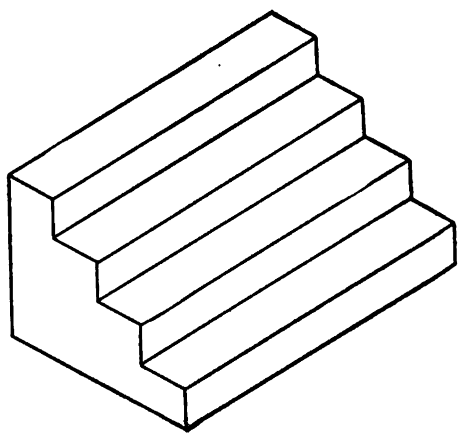


Fig. 171. Isometric of Stairs

projection of a point by one or two 30-degree co-ordinates; then vertically above this point, locate its height as taken from the elevation.

Figs. 166 to 173 give examples of the isometric of various objects.

Fig. 168 is the plan and elevation, and Fig. 169 the isometric, of a carpenter's sawhorse.

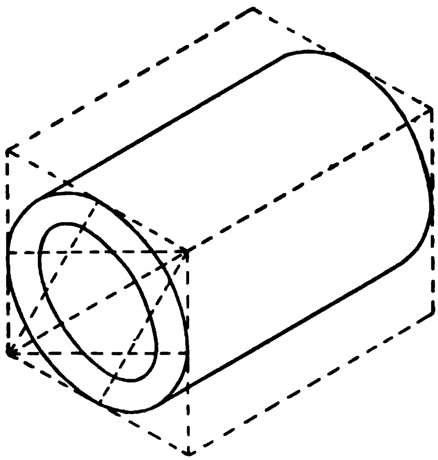


Fig. 172. Isometric of a Hollow Cylinder

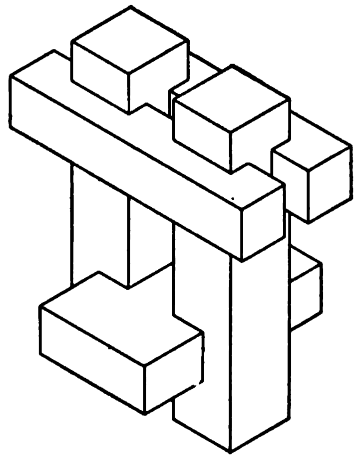


Fig. 173. Isometric of a Wooden Model

OBLIQUE PROJECTION

Comparison with Isometric Projection. In oblique projection, as in isometric, the end sought for is the same—a more or less complete representation, in one view, of any object. Oblique projection differs from isometric in that one face of the object is represented as if parallel to the vertical plane of projection, the others inclined to it. Another point of difference is that oblique projection cannot be deduced from orthographic projection, as is isometric.

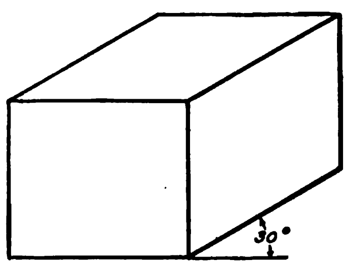


Fig. 174. Oblique View of Cube at 30 Degrees

Characteristics of Method. In oblique projection all lines in the front face are shown in their true lengths and in their true relation to one another, and lines which are perpendicular to this front face are shown in their true lengths at any angle that may be desired for any particular case. Lines not in the plane of the front face nor perpendicular to it must be determined by co-ordinates, as in isometric. It will be seen at once that this system

possesses some advantages over the isometric, as, for instance, in the representation of circles, as any circle or curve in the front face is actually drawn as such. Fig. 174, Fig. 175, and Fig. 176 show a cube in oblique projection with the 30-degree, 45-degree, and 60-degree slant, respectively. Fig. 177 shows a hollow cylinder in oblique projection. Figs 178, 179, 180, 182 are other examples of oblique projections. Fig. 180 is a crank arm.

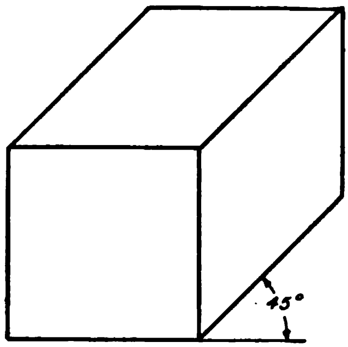


Fig. 175. Oblique View of Cube at 45 Degrees

The method of using co-ordinates for lines of which the true lengths are not shown, is illustrated by Figs 181 and 182. Fig. 182 represents the oblique projection of the two joists shown in plan and elevation in Fig. 181. The dotted lines in the elevation, Fig. 181, show the heights of the corners above the horizontal stick. The feet of these perpendiculars give the horizontal distances of the top corners from the end of the horizontal piece.

In Fig. 182 lay off from the upper right-hand corner of the front end a distance equal to the distance between the front edge of the

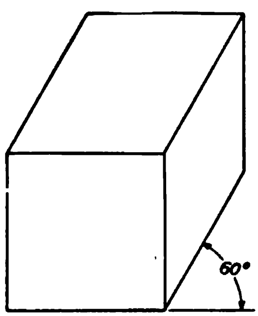


Fig. 176. Oblique View of Cube at 60 Degrees

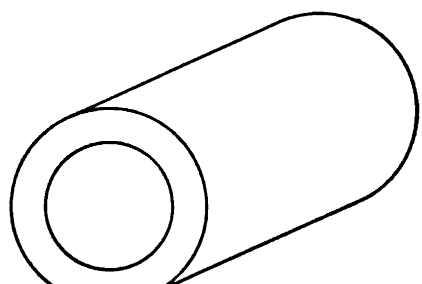


Fig. 177. Oblique View of Hollow Cylinder

inclined piece and the front edge of the bottom piece, Fig. 181. From this point draw a dotted line parallel to the length. The horizontal distances from the upper left corner to the dotted perpendicular are then marked off on this line. From these points verticals

are drawn, and made equal in length to the dotted perpendiculars of Fig. 181, thus locating two corners of the end.

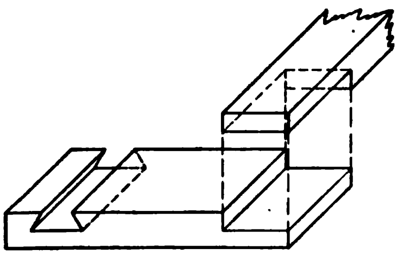


Fig. 178. Oblique View of a Miter Joint

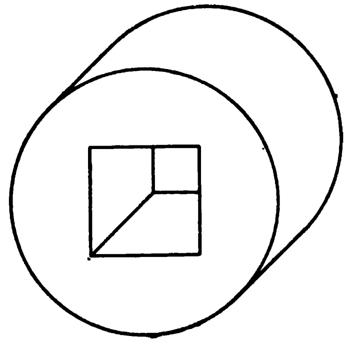


Fig. 179. Oblique View of Cylinder

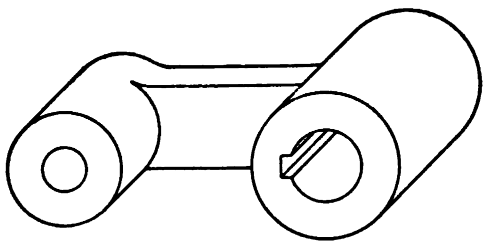


Fig. 180. Oblique View of Crank Shaft

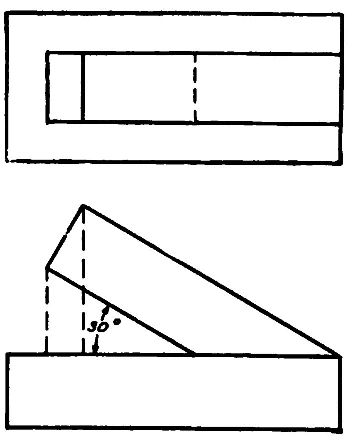


Fig. 181. Plan and Elevation of Wooden Brace

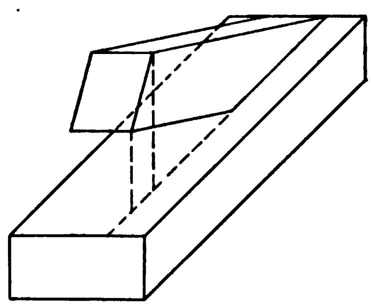


Fig. 182. Oblique View of Wooden Brace

LINE SHADING

Object of Line Shading. In finely finished drawings it is frequently desirable to make the various parts more readily seen by showing the graduations of light and shade on the curved surfaces. This is especially true of such surfaces as cylinders, cones, and spheres. The effect is obtained by drawing a series of parallel or converging lines on the surface at varying distances from one another. Sometimes draftsmen, themselves, vary the width of the lines. These lines are farther apart on the lighter portion of the surface, and closer together and heavier on the darker part.

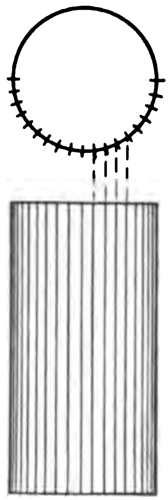


Fig. 183. Plan and Shaded Elevation of Cylinder

Fig. 183 shows a cylinder with elements drawn on the surface equally spaced on the plan. On account of the curvature of the surface, however, the elements are not equally spaced on the elevation, in order to give the effect of the graduations of light on the curved surface. The result is that in drawing the elevation of the cylinder, the distances between the elements are made gradually less from the center toward each side, thus giving a correct representation of the convexity of the cylinder. This effect is intensified by making the

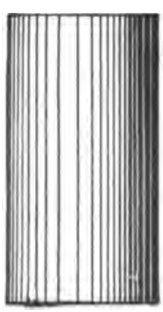


Fig. 184. Shaded Vertical Cylinder

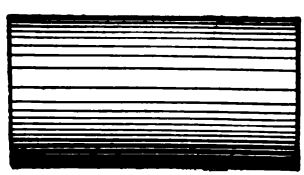


Fig. 185. Shaded Horizontal Cylinder

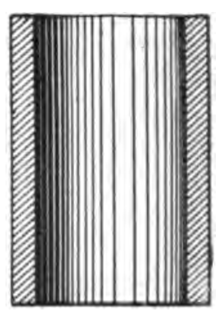


Fig. 186. Shaded Section of Hollow Cylinder

outside elements heavier as well as closer together, as shown in Figs. 184 to 190. Concavity is shown in the same manner, the

heavy shading always appearing on the left to indicate the deeper shadow, Figs. 186 and 188.

Fig. 184 is a cylinder showing the heaviest shade at the right, a method often used. Considerable practice is necessary to obtain good results; but in this, as in other portions of mechanical drawing, repetition is unavoidable. Fig. 185 represents a cylinder in a hori-

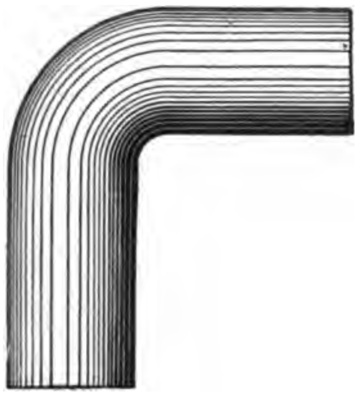


Fig. 187. Shaded Elbow Joint

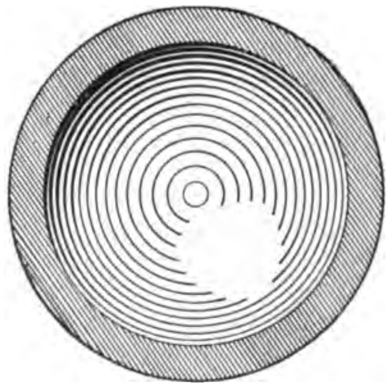


Fig. 188. Shaded Section of Hollow Sphere

zontal position, and Fig. 186 represents a section of a hollow vertical cylinder. Figs. 187 to 190 give other examples of familiar objects.

Fig. 189. Shaded Sphere

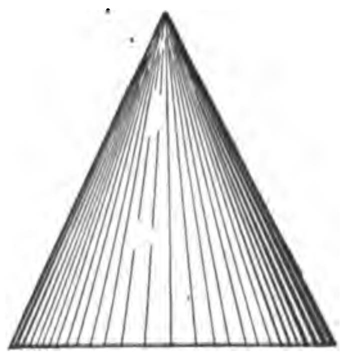


Fig. 190. Shaded Cone

In the elevation of the cone shown in Fig. 190 the shade lines should diminish in weight as they approach the apex. Unless this is done it will be difficult to avoid the formation of a blot at that point.

LETTERING

Types of Lettering. In the early part of this course, the inclined Gothic letter was described, and the alphabet given. The Roman, Gothic, and block letters are perhaps the most used for titles. These letters, being of comparatively large size, are generally made mechanically; that is, drawing instruments are used in their construction. In order that the letters may appear of the same height, some of them, owing to their shape, must be made a little higher than the others. This is the case with the letters curved at the top and bottom, such as C, O, S, etc., as shown somewhat exaggerated in Fig. 191. Also, the letter A should extend a little above, and V a little below, the guide lines, because if made of the same height as the others they will appear shorter. This is true of all capitals, whether of Roman, Gothic, or other alphabets. In the block letter, however, they are frequently all of the same size.

Size of Letters. There is no absolute size or proportion of letters, as the dimensions are regulated by the amount of space in which the letters are to be placed, the size of the drawing, the effect desired, etc. In some cases letters are made so that the height is greater than the width, and sometimes the reverse; sometimes the height and width are the same. This last proportion is the most common. Certain relations of width, however, should be observed. Thus, in whatever style of alphabet used, the W should be the widest letter; J the narrowest, M and T the next widest to W, then A and B. The other letters are of about the same width.

Vertical Gothic. In the vertical Gothic alphabet, the average height is that of B, D, E, F, etc., and the additional height of the curved letters and of the A and V is very slight. The horizontal cross lines of such letters as E, F, H, etc., are slightly above the center; those of A, G, and P slightly below.

Inclined Gothic. For the inclined letters, Fig. 192, 60 degrees is a convenient angle, although they may be at any other angle suited to the convenience or fancy of the draftsman. Many draftsmen use an angle of about 70 degrees.

Roman. The letters of the Roman alphabet, whether vertical, Fig. 193, or inclined, Fig. 194, are quite ornamental in effect if well made, the inclined Roman being a particularly attractive letter.

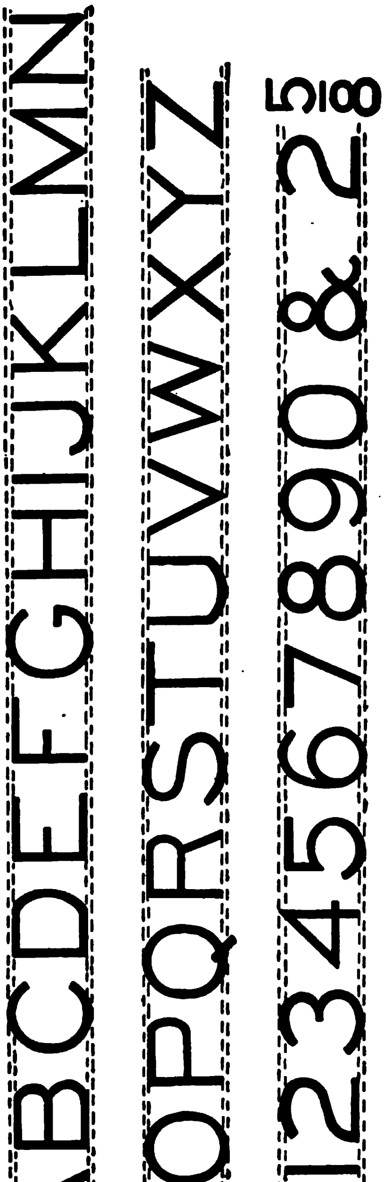


Fig. 191. Vertical Gothic Letters and Figures

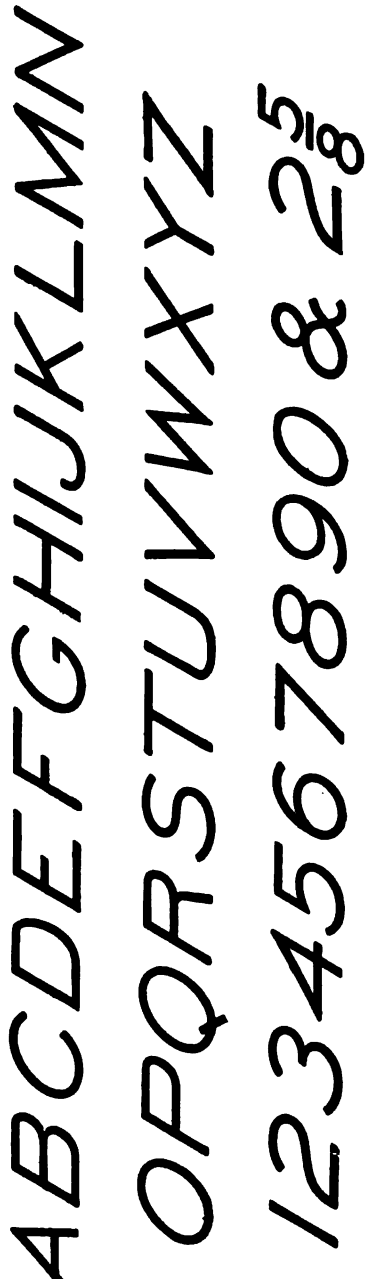


Fig. 192. Inclined Gothic Letters and Figures

Fig. 193. Vertical Roman Letters and Figures

Fig. 194. Inclined Roman Letters and Figures

although rather difficult to make. The block letter, Fig. 195, is made on the same general plan as the Gothic, but much heavier. Small squares are taken as the unit of measurement, as shown. The use of this letter is not advocated for general work, although

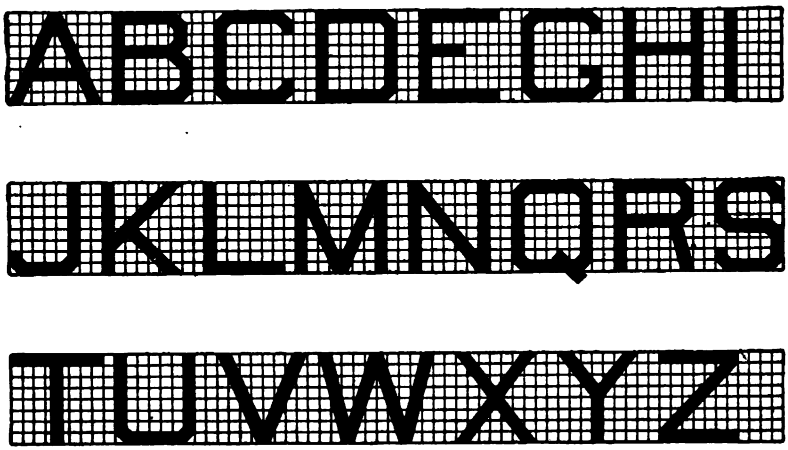


Fig. 195. Block Letters

if made merely in outline the effect is pleasing. The styles of numbers, corresponding with the alphabets of capitals given here, are also inserted. When a fraction, such as $2\frac{5}{8}$ is to be made, the proportion should be about as shown. For small letters, usually

Fig. 196. Vertical Gothic Lower-Case Letters

called lower-case letters, the height may be made about two-thirds that of the capitals. This proportion, however, varies in special cases.

Lower-Case Letters. The principal lower-case letters in general use among draftsmen are shown in Figs. 196, 197, 198, and 199.

The Gothic letters shown in Figs 196 and 197 are much easier to make than the Roman letters in Figs. 198 and 199. These letters,

abcdefghijklmn
opqrstuvwxyz

Fig. 197. Inclined Gothic Lower-Case Letters

however, do not give as finished an appearance as the Roman. As has already been stated in Mechanical Drawing, Part I, the inclined letter is easier to make because slight errors are not so apparent.

abcdefghijklmn
opqrstuvwxyz

Fig. 198. Vertical Roman Lower-Case Letters

Spacing. One of the most important points to be remembered in lettering is the spacing. If the letters are finely executed but

abcdefghijklmn
opqrstuvwxyz

Fig. 199. Inclined Roman Lower-Case Letters

poorly spaced, the effect is not good. To space letters correctly and rapidly requires considerable experience; and rules are of little

TECHNICALITY

Fig. 200. Sample of Letter Spacing

value on account of the many combinations in which letters are found. A few directions, however, may be found helpful. For

instance, take the word TECHNICALITY, Fig. 200. If all the spaces were made equal, the space between the L and the I would appear to be too great, and the same would apply to the space between the I and the T. The space between the H and the N and that between the N and the I would be insufficient. Usually, when the vertical side of one letter is followed by the vertical side of another, as in H E, H B, I R, etc., the maximum space should be allowed. Where T and A come together the least space is given, for in this case the top of the T frequently extends over the bottom of the A. In general, the spacing should be such that a uniform appearance is obtained. For the distances between words in a sentence, a space of about 1½ the width of the average letter may be used. The space, however, depends largely upon the desired effect.

Penciling before Inking. For large titles, such as those placed on charts, maps, and some large working drawings, the letters should be penciled before inking. If the height is made equal to the width, considerable time and labor will be saved in laying out the work. This is especially true with such Gothic letters as O, Q, C, etc., as these letters may then be made with compasses. If the letters are of sufficient size, the outlines may be drawn with the ruling pen or compasses, and the spaces between filled in with a fine brush.

Titles for Working Drawings. The titles for working drawings are generally placed in the lower right-hand corner. Usually a draftsman has his choice of letters, mainly because after he has become used to making one style he can do it rapidly and accurately. However, in some drafting rooms the head draftsman decides what lettering should be used. In making these titles, the different alphabets are selected to give the best results without spending too much time. In most work the letters are made in straight lines, although frequently a portion of the title is found lettered on an arc of a circle.

In Fig. 201 is shown a title having the words CONNECTING ROD lettered on an arc of a circle. To do this work requires considerable patience and practice. First, draw the vertical center line as shown at *C* in Fig. 201, then, draw horizontal lines for the horizontal letters. The radii of the arcs depend upon the general

arrangement of the entire title, and this is a matter of taste. The difference between the arcs should equal the height of the letters. After the arc is drawn, the letters should be sketched in pencil to find their approximate positions. After this is done, draw radial lines from the center of the letters to the center of the arcs. These

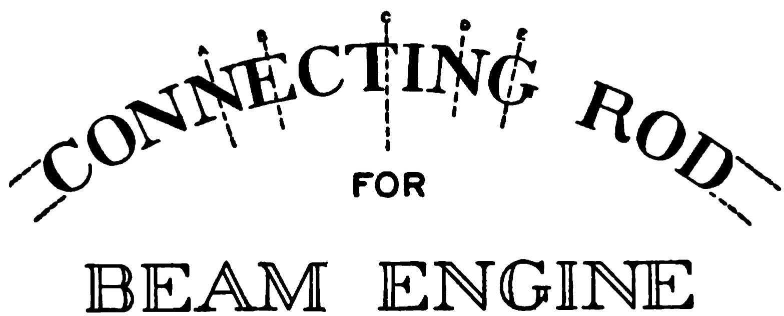


Fig. 201. Sample Title

lines will be the centers of the letters, as shown at *A*, *B*, *D*, and *E*. The vertical lines of the letters should not radiate from the center of the arc, but should be parallel to the center lines already drawn; otherwise the letters will appear distorted. Thus, in the letter *N*

Fig. 202. Sample Title

the two verticals are parallel to the line *A*. The same applies to the other letters in the alphabet. In making the curved letters such as O and C, the centers of the arcs will fall upon these center lines; and if the compasses are used, the lettering is a comparatively simple matter. In Fig. 202 is shown another title in which all the letters are in horizontal lines.

PLATES

Plates IX to XV, inclusive, are to be drawn by the student for practice in applying the principles of orthographic projection, intersections and developments, isometric and oblique projection, and for practice in lettering. These plates are to be made 11 inches by 15 inches outside, with a margin of ½ inch, making the clear space for the drawing 10 inches by 14 inches. All the plates are to be inked.

PLATE IX

After laying out the border line on the plate, draw a ground line horizontally across the upper part of the plate, 3 inches below the upper border line. On this ground line six figures, spaced as regularly as possible, are to be drawn, as follows:

1. Draw the projections of a line 1½ inches long which is parallel to both planes, 1 inch above the horizontal, and ¾ inch from the vertical.

2. Draw the plan and elevation of a line 1½ inches long which is perpendicular to the horizontal plane and 1 inch from the vertical. Lower end of line is ½ inch above *H*.

3. Draw the projections of two intersecting lines: one 2 inches long to be parallel to both planes, 1 inch above *H*, and ¾ inch from the vertical; and the other to be oblique to both planes and of any desired length.

NOTE. The idea for drawing the three figures referred to in 1, 2, and 3 can be obtained from Figs. 104 and 105 in this textbook.

4. Find the true length of a line whose vertical projection is 1¼ inches long, the left end on the ground line and inclined at 30 degrees. The horizontal projection has the left end ½ inch from *V*, and the right 1½ inches from *V*.

5. Find the true length of a line whose horizontal projection is 1 inch long, whose right end is ½ inch above the ground line, and inclined at 60 degrees. The vertical projection has the right end ½ inch below the ground line and the left 1 inch.

6. Find the true length of a line whose projections are perpendicular to the ground line. The horizontal projection is 2 inches long, the bottom end being ½ inch above the ground line. The vertical projection is 1 inch long, the top end being ½ inch below the ground line.

NOTE. The idea for drawing the figures referred to in 4, 5, and 6 can be obtained from Figs. 120 and 121 in this textbook.

In the lower half of the plate, four more figures are to be drawn, also spaced as regularly as possible, so that the finished plate will be well balanced:

7. Draw the plan and elevation of a round bolt with a square head. The head is to be uppermost in the elevation. The bolt

is to be 2 inches long and ½ inch in diameter. The head is to be ¾ inch square, ¼ inch thick, and have one face parallel to *V*.

8. Draw the plan and elevation of a round bolt having the same dimensions as in 7, but with a hexagonal head; the head to be uppermost in the elevation, and to be ¾ inch in width between faces ¼ inch thick, and to have one face parallel to *V*.

9. Draw the plan and elevation of a cylinder, perpendicular to *H*, 2 inches high and 2 inches in diameter, with a hole 1 inch in diameter passing vertically completely through it.

10. Draw the plan, elevation, and end view of a rectangular block 6 inches long, 2 inches wide, and 1 inch thick. One of the 2 inch by 6 inch sides is to be parallel to *H*. The right end is turned down to a cylindrical form 1 inch in length and 1 inch in diameter.

In all the work of this plate construction, lines should be fine dotted lines and should be inked in.

PLATE X

The figures on the reproduced Plate X in the back of this book give the outline of the work that is to be completed by the student. The dimensions given on this plate are to be used in working out the problem, but are not to appear on the finished plate. The first figure shown represents a rectangular block with a rectangular hole cut through from front to back. The other two figures represent the same block in different positions. In drawing these figures, the student must put in all construction lines in order to show how each view is obtained.

After completing the construction of the views as shown, the projection of four holes, ½ inch in diameter each, are to be drawn. One hole passes through the center of each end, and one hole through the center of each side. All these small holes pass completely through the large hole in the center of the block. Next, put two square projecting pieces on the front face of the block, on the center line, ½ inch from each end. These projecting pieces are to be ½ inch square and ¼ inch deep.

The projections of the four small holes and two projecting pieces are to be drawn in all views in the conventional manner, and the necessary construction lines for this work are to be left on the plate and inked in.

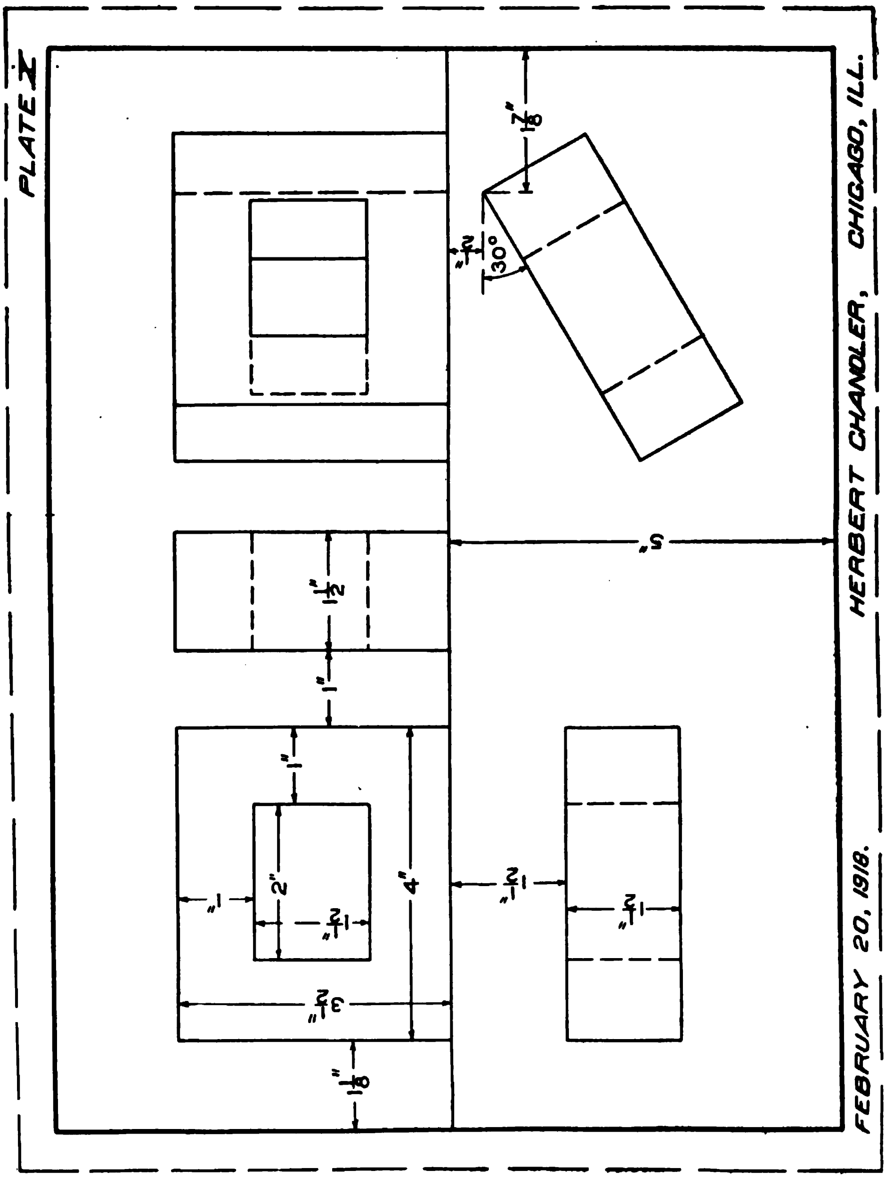


PLATE I
HERBERT CHANDLER, CHICAGO, ILL.
FEBRUARY 20, 1918.

PLATE XI

At the left of this plate draw the plan, front and side views of the monument shown in elevation on reproduced Plate XI in the back of the book. The total height of the monument is 6 inches. All four sides are alike except that the width of the base is 2 inches and the depth 1½ inches, and the width of the body of the monument is 1½ inches and the depth 1 inch. The height of the base is ½ inch, of body 3 inches, and the faces just above the base have a slope of 60 degrees with the horizontal. The width of the ridge at the extreme top of the monument is 1 inch.

The figures for the right side of the plate represent a pentagonal pyramid in three positions. The first position is the pyramid with the axis vertical. The height of the pyramid is 2½ inches, and the diameter of the circle circumscribed about the base 2½ inches. The center of the circle is 6 inches from the left margin and 2½ inches below the upper border line. Spaces between figures to be ½ inch.

In the second figure the pyramid has been revolved about the right-hand corner of the base as an axis, through an angle of 15 degrees. The axis of the pyramid, shown dotted, is therefore at 75 degrees. The method of obtaining 75 degrees and 15 degrees with the triangles was shown in Part I. From the way in which the pyramid has been revolved, all angles with *V* must remain the same as in the first position; hence the vertical projection will be the same shape and size as before. All points of the pyramid remain the same distance from *V*. The points on the plan are found on T-square lines through the corners of the first plan and directly above the points in elevation. In the third position the pyramid has been swung around, about a vertical line through the apex as axis, through 30 degrees. The angle with the horizontal plane remains the same; consequently the plan is the same size and shape as in the second position, but at a different angle. Heights of all points of the pyramid have not changed this time, and hence are projected across from the second elevation.

PLATE XII
DEVELOPMENTS

On this plate draw the developments of a truncated octagonal prism, and of a truncated pyramid having a square base. The

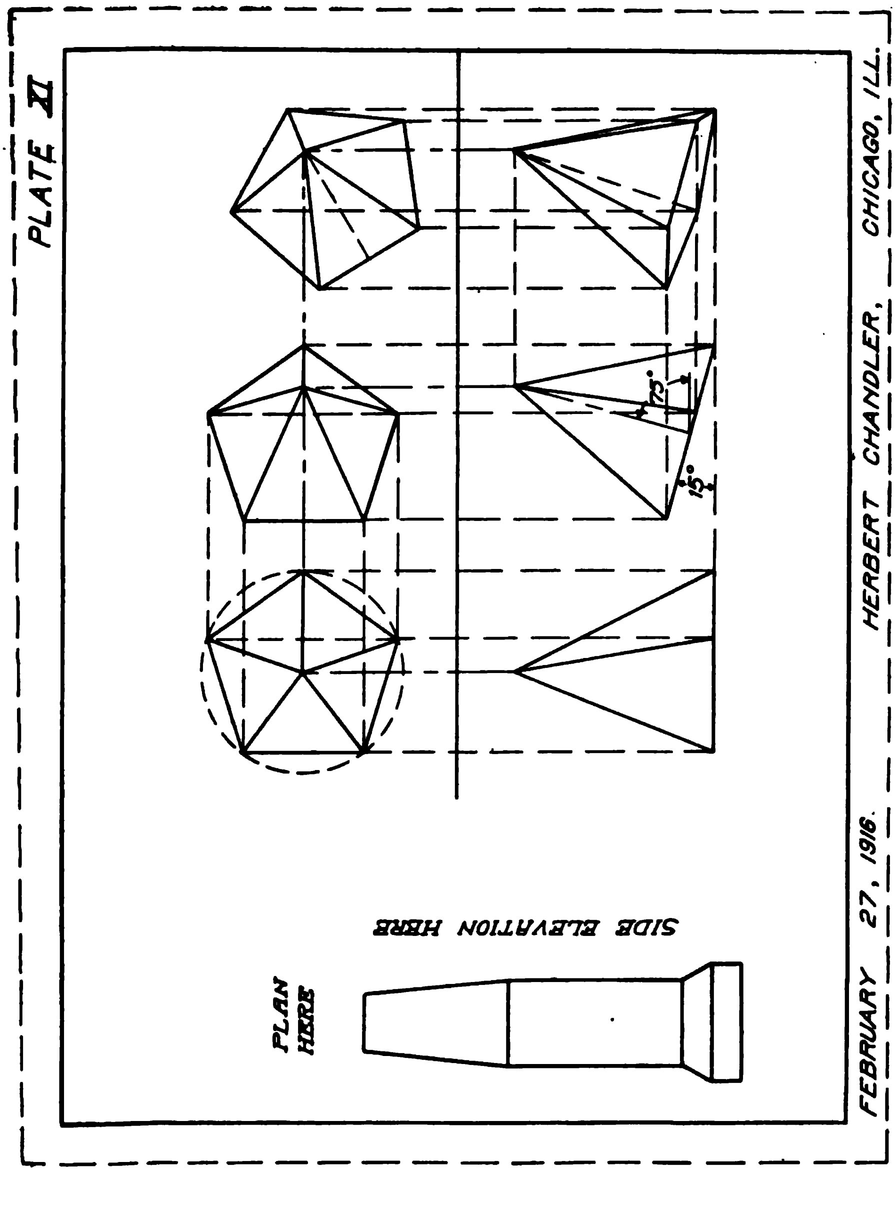


PLATE XI
75°
15°
SIDE ELEVATION HERE
PLAN HERE
HERBERT CHANDLER, CHICAGO, ILL.
FEBRUARY 27, 1916.

arrangement on the plate is left to the student; but it is suggested that the truncated prism and its development be placed at the left,

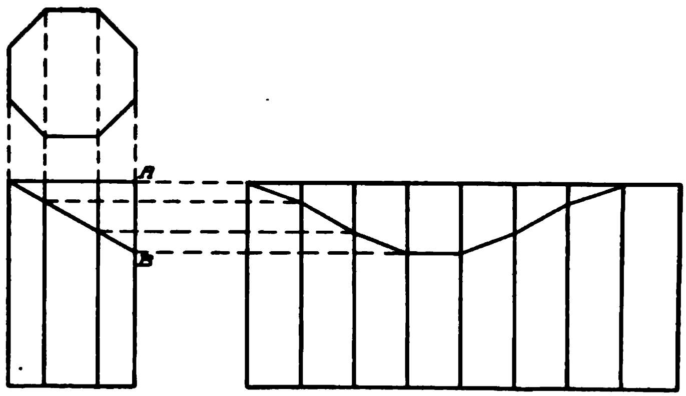


Fig. 203. Plan, Elevation, and Development of an Octagonal Prism

and that the development of the truncated pyramid be placed under the development of the prism; the truncated pyramid may be placed at the right.

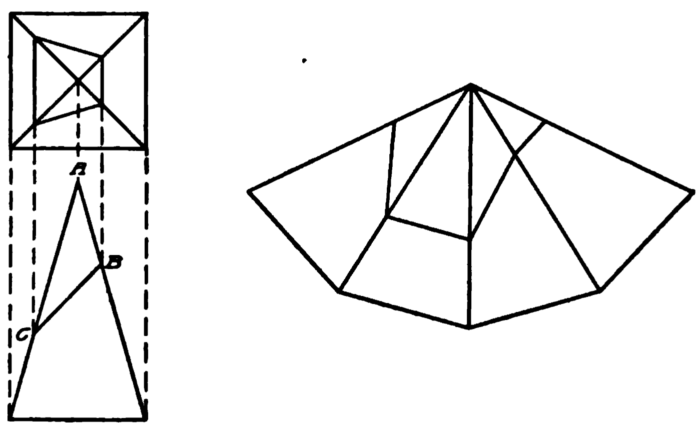


Fig. 204. Plan, Elevation, and Development of a Square Pyramid and Cutting Plane

The prism and its development are shown in Fig. 203. The prism is 3 inches high, and the base is inscribed in a circle 2¼ inches in diameter. The plane forming the truncated prism is passed as indicated, the distance AB being 1 inch. Ink a sufficient number of construction lines to show clearly the method of finding the development.

The pyramid and its development are shown in Fig. 204. Each side of the square base is 2 inches, and the altitude is $3\frac{1}{2}$ inches. The plane forming the truncated pyramid is passed in such a position that AB equals $1\frac{3}{8}$ inches, and AC equals $2\frac{1}{2}$ inches. In this figure the development may be drawn in any convenient position, but in the case of the prism it is better to draw the development as shown. Indicate clearly the construction by inking the construction lines.

PLATE XIII

ISOMETRIC AND OBLIQUE PROJECTION

In the upper left quarter of this plate draw the isometric projection of the block shown on reproduced Plate X, in the back of this book, taking the dimensions from your finished Plate X. The idea for this problem can be obtained by referring to Fig. 158 in this textbook.

In the upper right quarter of this plate draw the isometric projections of the two round bolts shown in Figs. 7 and 8, on Plate IX, taking dimensions from your finished Plate IX.

In the lower half of this plate draw, at 45 degrees, the oblique projections of the cylinder and the rectangular block, shown in Figs. 9 and 10 on Plate IX, taking dimensions from your finished Plate IX. The idea for this can be obtained by referring to Figs. 175 and 179 in this textbook.

PLATE XIV

FREE-HAND LETTERING

On account of the importance of free-hand lettering, the student should practice it at every opportunity. For additional practice, and to show the improvement made since completing Part I, lay out Plate XIV in the same manner as Plate I, and letter all four rectangles. Use the same letters and words as in the lower right-hand rectangle of Plate I.

PLATE XV

LETTERING

First lay out Plate XV in the same manner as previous plates. After drawing the vertical center line, draw light pencil lines as

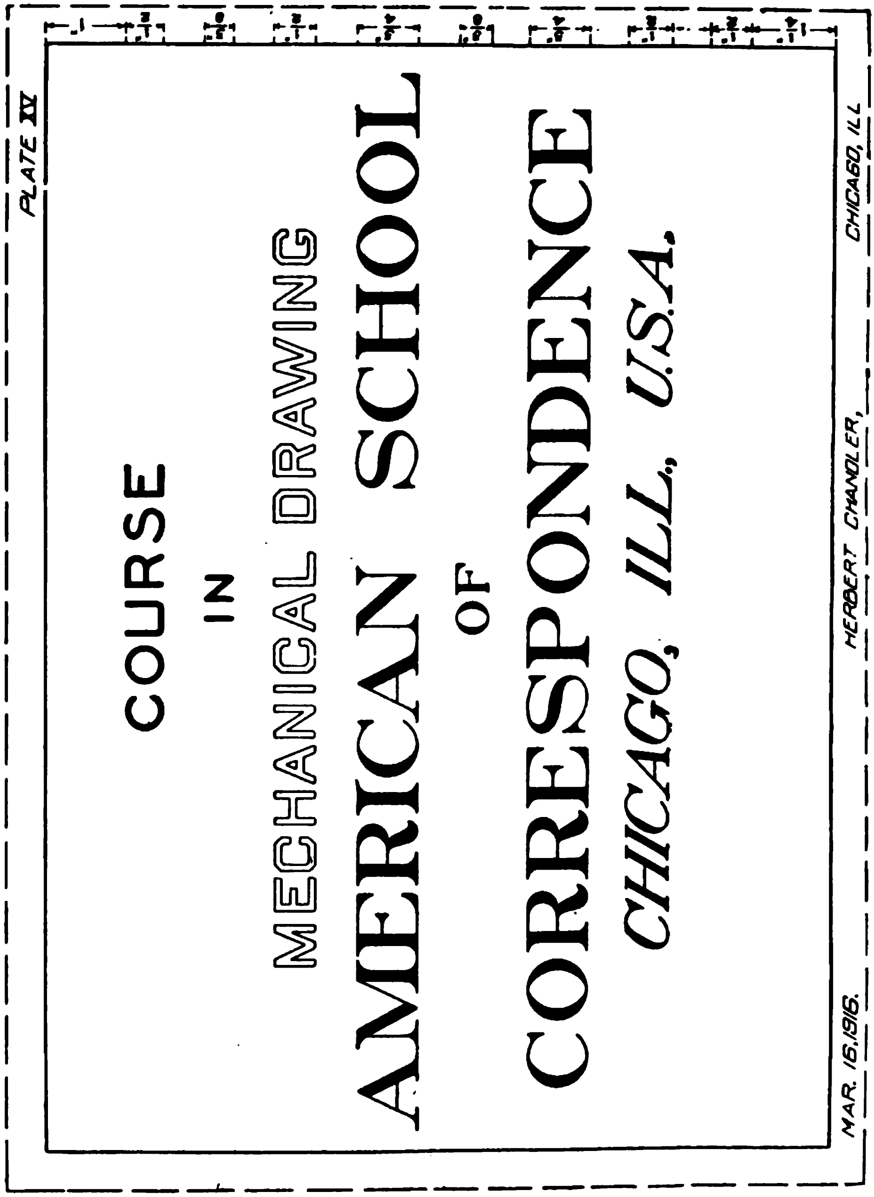


PLATE XV
COURSE
IN
MECHANICAL DRAWING
AMERICAN SCHOOL
OF
CORRESPONDENCE
CHICAGO, ILL., U.S.A.
MAR. 16, 1916.
HERBERT CHANDLER,
CHICAGO, ILL.

guide lines for the letters. The height of each line of letters is shown on the reproduced plate. The distance between the letters should be ½ inch in every case. The spacing of the letters is left to the student. He may facilitate his work by lettering the words on a separate piece of paper, and finding the center by measurement or by doubling the paper into two equal parts. The styles of letters shown on the reproduced plate should be used.

REVIEW QUESTIONS

REVIEW QUESTIONS

ON THE SUBJECT OF

PATTERN MAKING

PART I

1. What are some of the causes of warping in lumber?

2*a*. When is metal used for patterns?

2*b*. Why is metal better than wood?

3. Why should plenty of oil be used on an oil-stone?

4. Explain with sketch the method used in casting a small hollow cylinder.

5. For what parts of the pattern must the shrinkage rule be used?

6. Is the draft always the same on all parts of a pattern?

7. What is the usual allowance for finish on small castings?

8. When must a greater amount be allowed?

9. Under what conditions will a seasoned board warp?

10. What wood is most commonly used in pattern making?

11. Explain the difference in the manner in which saws cut when ripping and when crosscutting.

12. In what direction should the grindstone revolve when grinding scraping tools or other tools having a short bevel?

13. When is dry parting sand used?

14. Should a shrinkage rule be used when making a core box?

15. Why must the pattern maker know something of Mechanical Drawing?

16. When it is necessary to use a wide piece for a pattern, how may the tendency to warp be counteracted? Make sketch.

17. Explain the use of the cap-iron of a plane.

18. What portion of the skew chisel does the cutting?

19. What is meant by shrinkage in pattern making?

20. How are the exact proportions of shrinkage obtained for different parts of the pattern?

21*a*. What is the usual proportion of draft to each twelve inches of surface on the face of a pattern for a cast-iron pulley?

21*b*. What proportions on the inside of the rim and on the hub?

22. When is it necessary to use mahogany, cherry, or maple for patterns?

23. What is lead in a plane-iron, and what determines the amount?

24. Explain the use of a flask in moulding, and describe the two principal parts.

25. What allowance must be made on the pattern for shrinkage when the casting is made of iron?

26. Explain what is meant by *draft* in pattern making?

27. How should lumber for patterns be seasoned?

28. When a large piece is to be used for turning, should it be cut from a plank of the required thickness or glued up out of thinner stock? Give reasons for answers.

29. Explain the methods of grinding the brad-awl and the advantages of each method.

30. Explain the use of core prints.

31. What is the allowance for shrinkage of brass?

32. What are the usual allowances for draft?

33. What is meant by *finish* in pattern making?

34. When gluing up pattern stock, how is the pressure necessary to bring the glued surfaces in close contact usually obtained?

REVIEW QUESTIONS

ON THE SUBJECT OF

PATTERN MAKING

PART II

1. What are rapping plates?

2. Describe the process of gluing two thin pieces having large surfaces.

3. How is end wood treated if it is to be glued to other wood?

4. Explain why the upper core print sometimes has excessive draft, while the lower has but little draft.

5. What are fillets, and where are they used on patterns?

6. Give the dimensions for the arms of a six-arm pulley 40 inches in diameter and 12-inch face: (a) Width and thickness at hub. (b) Width and thickness at rim.

7. The pulley mentioned in Question 6 is to be fitted to a shaft $2\frac{9}{16}$ inches in diameter. (a) What should be the diameter of the hub? (b) What should be the length of hub?

8. What is a follow board, and when is its use necessary?

9. A pair of tight and loose pulleys 12 inches in diameter and $6\frac{1}{4}$ inches wide of face, are to be fitted to a $1\frac{11}{16}$-inch shaft. (a) Give diameter of the hub. (b) Give length of hub.

10. What must be the outside diameter of the original wooden pattern for the rim of a pulley with six arms, the diameter of the finished pulley to be 30 inches and the width of face 9 inches?

11. (a) In the above pulley what should be the width and thickness of the arms at the rim? (b) What should be the width and thickness of the arms at the hub?

12. What are core prints and when do they form a necessary part of a pattern?

13. How are the two parts of a parted pattern held together for turning? Give two methods.

14. What are the proportions of alcohol and shellac gum for pattern maker's shellac varnish?

15. Is it always necessary to make a pattern in two parts?

16. How is colored shellac varnish made? (a) How is black made? (b) How red?

17. Give a sketch, including all dimensions, of the pattern for a plain brass cylinder which is to be finished "all over", the finished sizes being 6 inches long, 4 inches outside diameter, and $3\frac{1}{2}$ inches inside diameter. All shrinkage rule measurements, allow $\frac{3}{32}$ inch for finish.

18. What is a core box, and for what purpose is it used?

19. What is used to give a hard, smooth surface to a completed pattern?

20. What color should be used for the inside of a core box?

21. How can the pattern for a small hollow cylinder be molded if made in one piece (not parted)?

22. Why are core prints shellacked in a different color from the body of the pattern?

23. What are dowel pins, and why are they used in a parted pattern?

24. How long a time should each coat of shellac have for drying before another coat is applied?

25. Give sketch showing shape and dimensions of core box for pattern mentioned in Question 17.

26. It is required to make the pattern for a five-arm 15-inch hand-wheel, the rim and hub of which are to be turned and finished. The finished diameter of the round rim is to be $1\frac{5}{8}$ inches, and of hub $2\frac{1}{2}$ inches. Allowing $\frac{1}{16}$ inch for finish, give all dimensions for the wooden pattern, including width and thickness of arms at the rim and at the hub.

27. Give a sketch and all dimensions (shrinkage rule measurements) of the pattern for a cast-iron cylinder having a projecting flange, on each end (see Fig. 149), the cylinder to be bored out and finished all over, the finished sizes being as follows: Length 8 inches, diameter of flanges $5\frac{1}{2}$ inches, thickness of flanges $\frac{3}{8}$ inch, the diameter of the body of the cylinder outside 4 inches, and inside $3\frac{1}{4}$ inches, allowing $\frac{1}{8}$ inch for finish.

28. Can the above pattern be molded without being parted?

REVIEW QUESTIONS

ON THE SUBJECT OF

PATTERN MAKING

PART III

1. What allowance should be made for expansion in a dry-sand core?

2. Why is it not advisable to use a scratch awl for making center and construction lines?

3. What is a radial gage?

4. Discuss the use of the parallel drawing device.

5. Where should identification marks be placed, and why should these not occur on the ends of the draw plate?

6. Discuss the use of the pattern board, giving a concrete example.

7. What are the allowances for shrinkage in the construction of a wooden pattern of a shaft hanger bearing cap?

8. Sketch a plan view of two cores set together so that the space between forms the mold for the guide vanes.

9. Discuss machine molding, giving its advantages and disadvantages.

10. Sketch a radial sectional view of a pattern for a flange coupling.

11. Give a complete description of the method used in making a spur-gear pattern.

12. Discuss the correct method of stock preparation.

13. When using the drag machine how many molds can be made at one operation?

14. When using the drag machine, why cannot the pattern be bolted directly to the draw plate?

15. Discuss the use of a vibrator.

16. When and why are trial castings made?

17. What is an expanding pattern and when is it used?

18. Discuss the use of the double-draw stripping-plate machine.

19. Give the correct method for forming pattern for a short length of cast-iron pipe 6 inches inside diameter.

20. Discuss the preservation of master pattern.

INDEX

The page numbers of this volume will be found at the bottom of the pages; the numbers at the top refer only to the section.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

19 My'32			
29 My'33			
22 Ja'37			
27 Oc 37			
20 Ja'38			
6 Je'38			
30 Je'38			
21 Ja'39			